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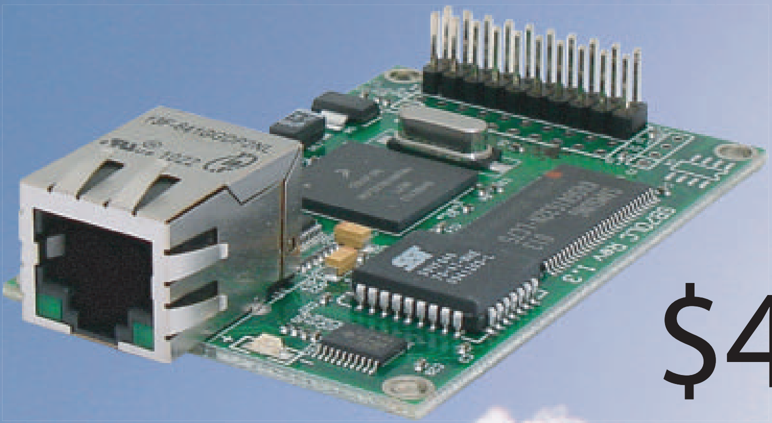

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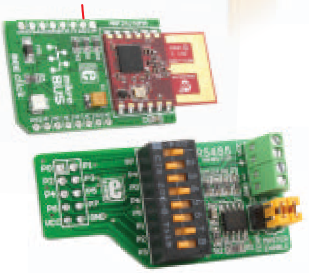

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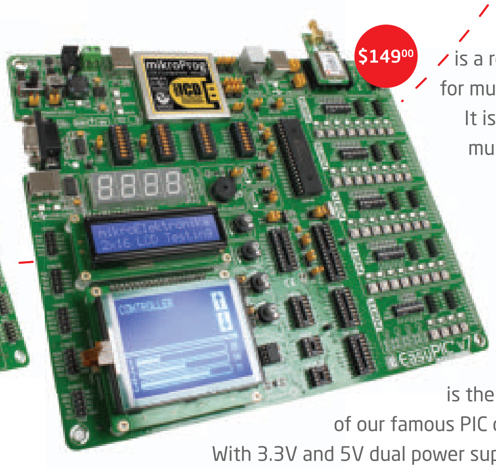

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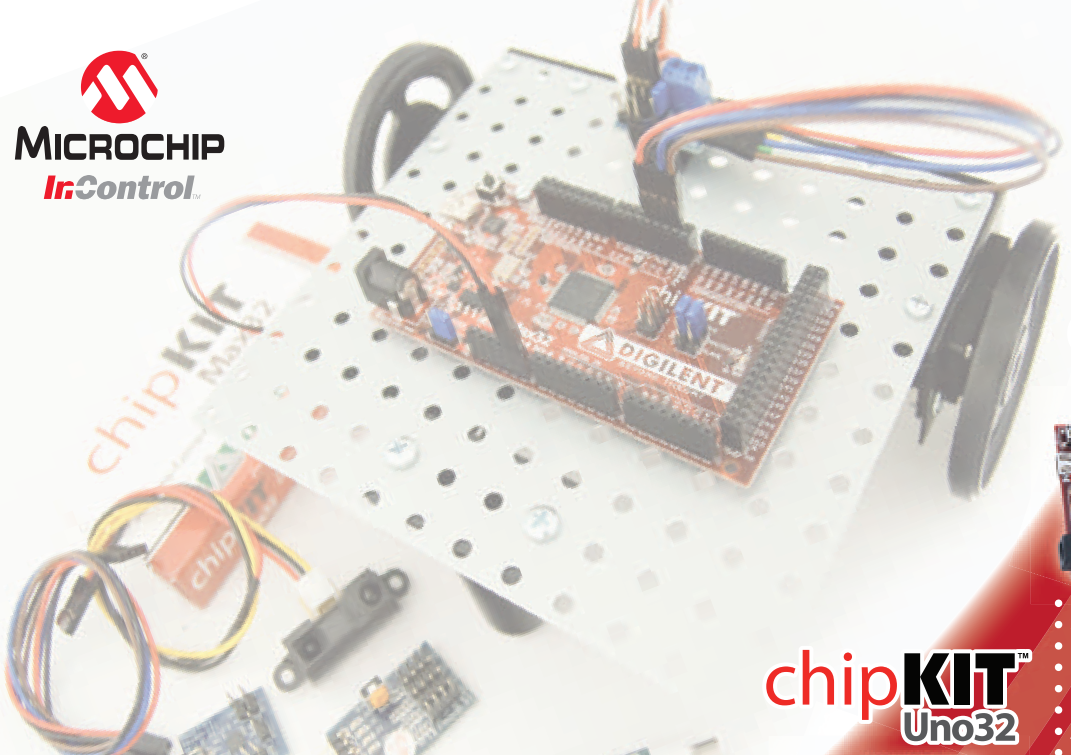

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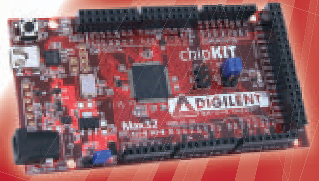

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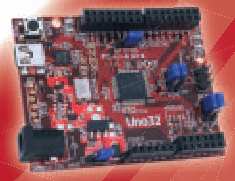

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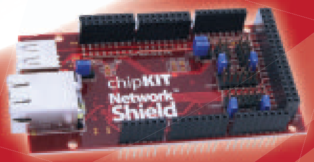

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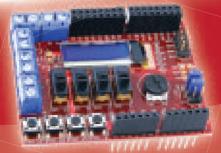

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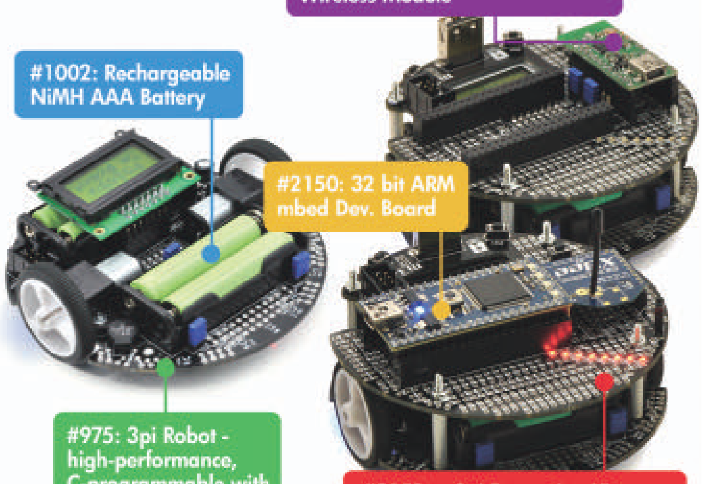


#1336: Wixel USB Programmable Wireless Module

#1002: Rechargeable NiMH AAA Battery

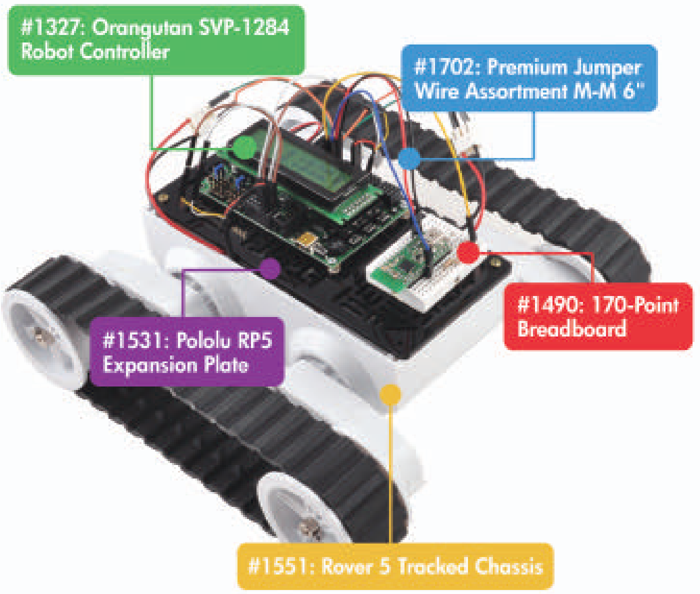
#2150: 32 bit ARM mbed Dev. Board

#975: 3pi Robot - high-performance, C-programmable with ATmega328P MCU

#2152: m3pi Expansion Kit - enables use of the mbed Dev. Board with the 3pi Robot. Also available fully assembled (#2151).

DIY Projects:

Simple Tracked Robot



#1327: Orangutan SVP-1284 Robot Controller

#1702: Premium Jumper Wire Assortment M-M 6"

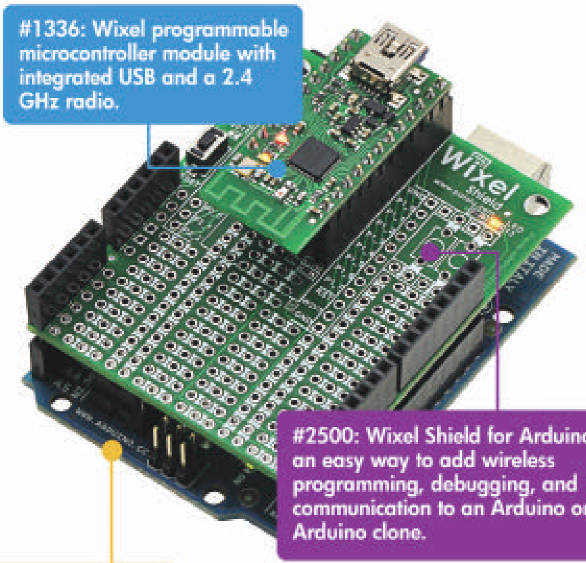
#1531: Pololu RP5 Expansion Plate

#1490: 170-Point Breadboard

#1551: Rover 5 Tracked Chassis

Programmable Controllers:

Wixel and Wixel Shield



#1336: Wixel programmable microcontroller module with integrated USB and a 2.4 GHz radio.

#2500: Wixel Shield for Arduino - an easy way to add wireless programming, debugging, and communication to an Arduino or Arduino clone.

#1616: Arduino Uno

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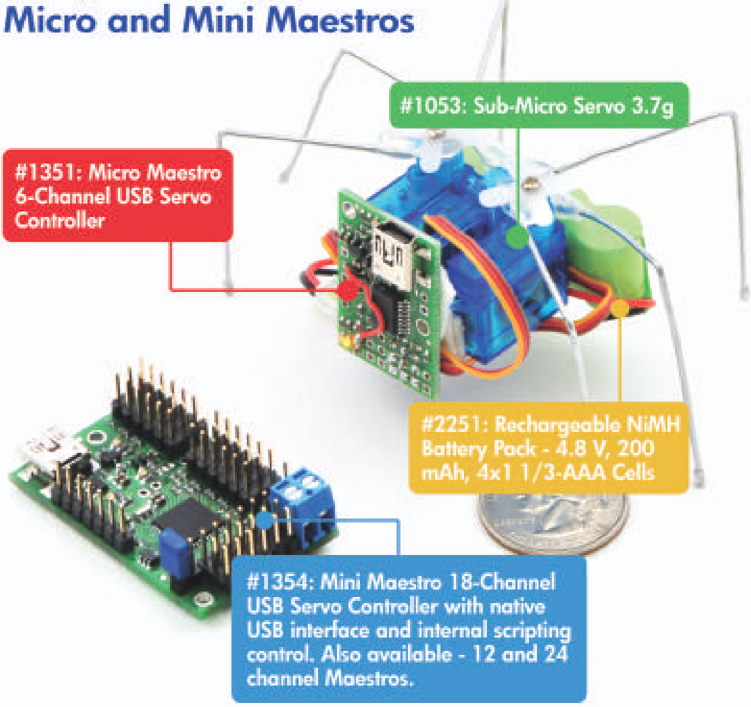

#1053: Sub-Micro Servo 3.7g

#1351: Micro Maestro 6-Channel USB Servo Controller

#2251: Rechargeable NiMH Battery Pack - 4.8 V, 200 mAh, 4x1 1/3-AAA Cells

#1354: Mini Maestro 18-Channel USB Servo Controller with native USB interface and internal scripting control. Also available - 12 and 24 channel Maestros.

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Projects & Features

28 DDS and the Electronic Music Box

Learn about direct digital synthesis and how you can make music with digitally generated analog signals.

■ By Craig A. Lindley

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■ By Keith Bayern

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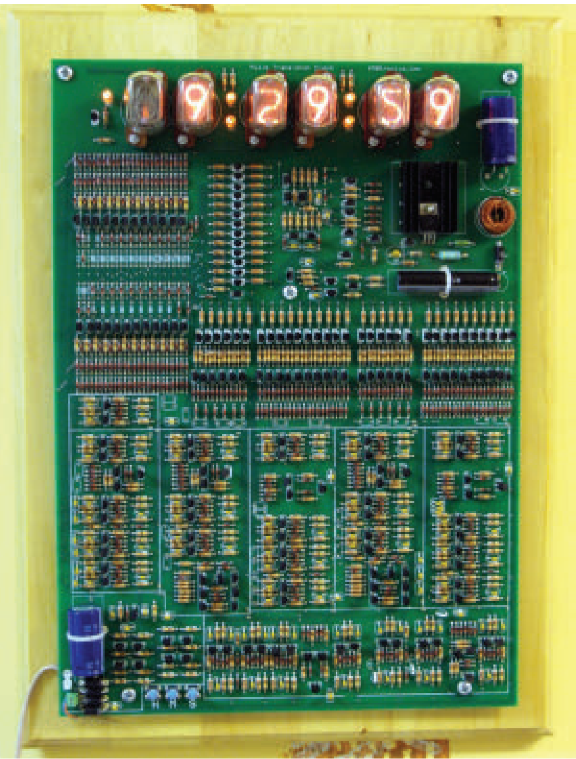
Data storage, user input, printing, audio, video, and network communications are just a few of the functions that off-the-shelf USB devices can perform. Learn how to include USB devices in your creations with the BeagleBoard-xM.

■ By Jan Axelson



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Discover and harness the power of widgets to use on your Experimenter board.

■ By Thomas Kibalo

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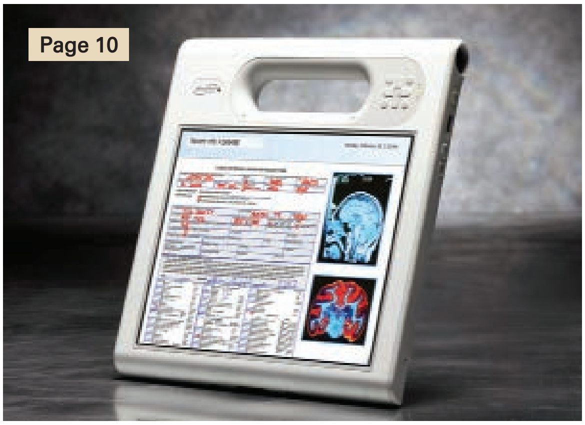

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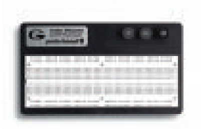
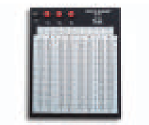


840 Tie-points, with plastic backplate

$23.00

PB-104



3060 Tie-points, w/ aluminum backplate

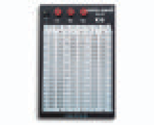
$75.00

PB-101T

1260 Tie-points, w/ aluminum backplate

$19.50

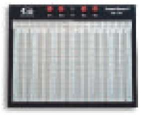
PB-103



2250 Tie-points, w/ aluminum backplate

$50.00

PB-105



4560 Tie-points, w/ aluminum backplate

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PB-83E

830 Tie-points

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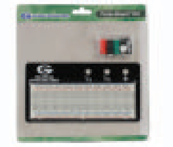
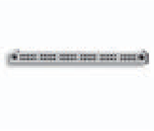


Bus Strip

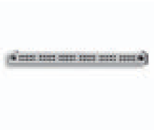
QT-35B



60 Tie-points

$4.00

QT-47B



80 Tie-points

$5.00

QT-59B

100 Tie-points

$6.00

GS-060

60 Tie-points

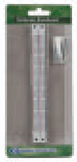
$2.50

GS-080

80 Tie-points

$3.00

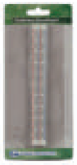
GS-090



90 Tie-points

$3.50

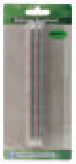
GS-100



100 Tie-points

$3.25

GS-100T



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EXP-300

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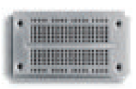
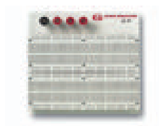
EXP-350



270 Tie-points

$7.00

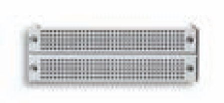
PB-60



1680 Tie-points

$51.00

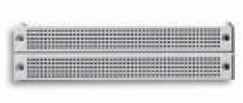
QT-35S



350 Tie-points

$6.00

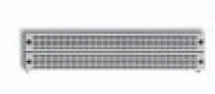
QT-47S



470 Tie-points

$8.00

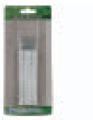
QT-59S



590 Tie-points

$10.00

GS-351



350 Tie-points

$3.75

GS-400

400 Tie-points

$5.50

GS-470

470 Tie-points

$5.00

GS-590

590 Tie-points

$6.50

GS-630

630 Tie-points

$5.50

GS-630T

630 Tie-points

$6.50

GS-830

830 Tie-points

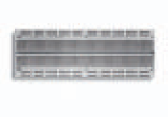
$8.00

GS-830T

830 Tie-points

$9.00

USB-100



840 Tie-points

$13.00

by Bryan Bergeron, Editor

DEVELOPING PERSPECTIVES

A Matter of Time

Adding real time clock (RTC) capabilities to a circuit can often change a ho-hum project into something with a wow factor. In basic terms, an RTC enables you to synchronize or time-stamp events to an easily understood time reference. By easily understood, I don't mean the number of clock cycles since a computer or microcontroller was turned on, but ordinary day, date, hours, minutes, and seconds, in either a 12- or 24-hour format.

A time-aware project that I worked on recently was a simple activity timer for my nephew. He's tasked with practicing piano 30 minutes every evening from 6:30 to 7:00 pm, Monday through Saturday. I use a passive infrared (PIR) detector ($8, **Parallax.com**) aimed at the area in front of his piano. He can move in and out of the area all day and nothing registers. However, when it's his normal practice time, a huge event timer starts up and begins counting up when he's in range of the PIR. I used four massive 6.5" seven-segment LEDs ($15 each, **Sparkfun.com**), an Arduino Uno, and a DS1307-based RTC breakout board ($15, SparkFun) to control the display, handle the PIR detector, and keep track of elapsed time.

The display automatically shuts off and resets to zero at 8:00 pm — long enough for my nephew's parents to verify he was in front of his piano at the specified time. Of course, the timer doesn't determine the quality of his practice and I suspect he'll learn to reprogram the Arduino when he's a year or two older. For now, it's a good practice tool.

Another time-dependent project is a data logger built around an Arduino, a set of sensors, and a microSD memory card. The data logger — which tracks environmental conditions over time — started as an Arduino connected to my PC and a simple data logging and display program written in Processing (**www.Processing.org**). That was a waste of energy and also limited my ability to work with some applications. Another DS1307-based RTC breakout board, an external power supply, and microSD Shield ($15, SparkFun) freed up my PC for other tasks.

There are several ways of adding time capabilities to a microcontroller-based project, and some microcontrollers have built-in timers. In the RTC chip world, Maxim/Dallas Semiconductor (DS) seems to have the major market share with over 80 RTC chips to choose from. The chips vary in operating temperature range, accuracy, onboard RAM, ability to charge the battery, and need for external components. Some chips require an external capacitor and standard 32.768 kHz crystal oscillator, while others require only five or 3.3 VDC. RTC chips of similar capabilities are also available from Texas Instruments, NXP (Philips), STMicroelectronics, and Intersil.

As noted in the above two projects, I've had great results from the DS1307. SparkFun's breakout board is a little pricy at $15, given an Arduino Pro sells for about $20. However, I've found the breakout board to be accurate and reliable in a home environment. According to the spec sheet, accuracy is mainly a function of the crystal and the degree of match between the capacitive load of the oscillator circuit and the capacitive load for which the crystal was trimmed.

The lithium coin cell battery has a theoretical nine year lifetime. Setup is simple — in part because SparkFun ships the RTC set to MST. Changing the date and time — or zeroing the clock for data logging or other timing purposes — involves running a short program. The DS1307 should work with any microcontroller that supports two-wire I^{2}C communications.

An alternative to the DS1307 breakout board is to purchase a DS1302, a 32 MHz crystal, and a capacitor from Parallax for about $7. According to the Parallax forums, the SD1303 is a good option if you already have a battery backup or want to integrate RTC capabilities into a custom printed circuit board. I haven't used the chip, however.

The DS series of RTCs is great for applications that use time in the standard second, minute, hour, day, month, and year format. If you need higher accuracy than a minute or so a month or if your circuit is exposed to significant variation in temperature, then consider a more capable DS chip such as the DS3234. This surface-mount chip includes an internal temperature-compensated crystal and two alarms. SparkFun sells the bare chip for $10 and an easy-to-use breakout board for $20 — without the coin cell battery.

The list of possible applications for experimentation is virtually endless. You could create an electronic doorbell with an MP3 shield and an RTC chip to produce different chimes for different times of the day. If you like getting up with the sun, you can build an alarm clock that tracks the time of local sunrise, and so is independent of ambient light. If you're into astronomy, you can add RTC capabilities to your motorized positioning program to auto-track targets, with corrections for local time changes.

For information on the design considerations for RTC chips, check out the technical documents on the Maxim/DS site at **www.maxim-ic.com**. Texas Instruments offers documentation and application notes for their BQ series of RTC chips on their site at **www.ti.com**. NXP (**ics.nxp.com**) offers a few good white papers on the use of their RTC chips in various applications. The best way to learn about this technology, of course, is to get your hands on a chip and start experimenting. **NV**

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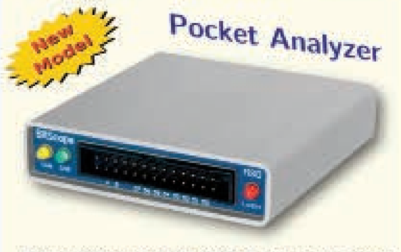

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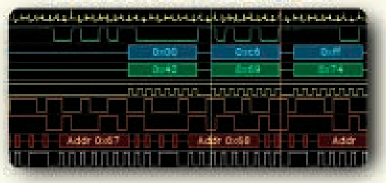

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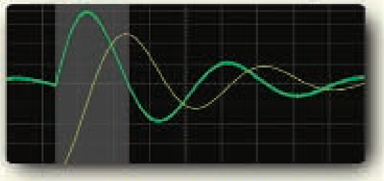

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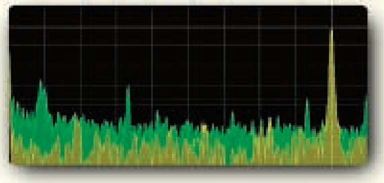

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TECH KNOWLEDGEY 2012

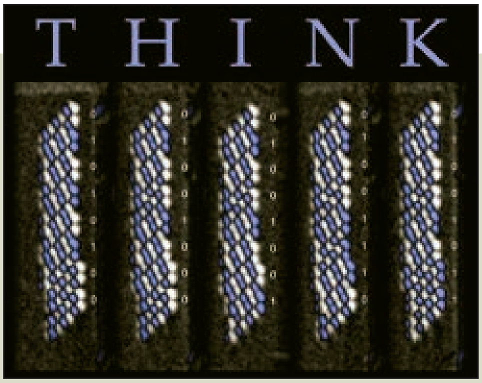
EVENTS, ADVANCES, AND NEWS

■ BY JEFF ECKERT

ADVANCED TECHNOLOGY

MAGNETIC MEMORY LIMIT ATTAINED

After about 30 years of investigation into computing and nanotechnology research, IBM Research (**www.research.ibm.com**) appears to have reached the physical limit of how compact data storage can be. As reported in the journal *Science*, researchers were able to create the world's smallest memory bit using only 12 atoms. The approach is based on ferromagnets (yes, like the Pizza Hut magnet on your refrigerator) in which a magnetic interaction between their constituent atoms aligns their spins in a single direction. Existing ferromagnetic RAM devices work pretty much like Flash memories, but so far have suffered from lower storage densities and other drawbacks. One of the problems is that — until now — the magnetization of one bit required a magnetic field that screwed up the state of neighboring bits. However, the IBM folks figured out how to use a scanning tunneling microscope to create a group of 12 "antiferromagnetically coupled" atoms that stored a bit of data for a matter of hours at low temperatures. Because of their alternating spin directions, bits created this way can be packed much more closely without any mutual disruption.



■ A 96 atom magnetic byte imaged in five different magnetic states representing "THINK" in ASCII.

To put this in practical terms, the computer you use today uses about one million atoms per storage bit, so we're looking at the possibility of building hard drives that are 100 times more dense than existing devices. Late last year, Hitachi introduced a drive that puts 4 TB on a 3.5 inch platter, so we're looking at the possibility of installing a 400 TB drive at some point. In rough terms, we're talking about enough space to store a quarter of a million movies. That's the equivalent of having 40 million hard drives installed in my old Kaypro 4. ▲

BAD AIM? WHO CARES?

As is well known, modern bullets are fired through rifled barrels to generate a football-like spin that keeps them flying straight. This is a great thing if you have aimed properly and taken range, wind drift, and other factors into consideration. If not, you're still likely to miss. This reality led a couple of engineers — who also happen to be hunters — at Sandia Labs (**www.sandia.gov**) to think about the possibility of self-guided bullets that can adjust their own course and find the target, even if the shooter failed to earn his marksmanship merit badge. The result is that researchers Red Jones and Brian Kast (with the aid of some colleagues) have created and patented a dart-like projectile that — when fired from a smooth-bore rifle — can steer itself over a distance of more than a mile. The four inch bullet is tipped with an optical sensor that focuses on a laser-illuminated mark and feeds data to guidance and control electronics. In response, an eight-bit CPU operates electromagnetic actuators that move small fins to alter the trajectory. Computer simulations show that an unguided bullet under real world conditions is likely to miss a target by about 30 ft (9 m), but the guided one would come within 8 in (0.2 m). Course corrections are made 30 times per second, and testing has shown that the bullet can reach speeds of 2,400 FPS (feet per second) using standard gunpowder. Plus, its relative simplicity (no inertial measuring system is required, unlike guided missiles) means that it won't be prohibitively costly to produce. The result is a patented design that could be very good news for the US military and law enforcement agencies (but not so hot for Bambi and Thumper). ▲

Photo courtesy of Sandia National Laboratories.

■ An LED attached to a self-guided bullet shows the track to the target.

Discuss this article in the *Nuts & Volts* forums at http://forum.nutsvolts.com.

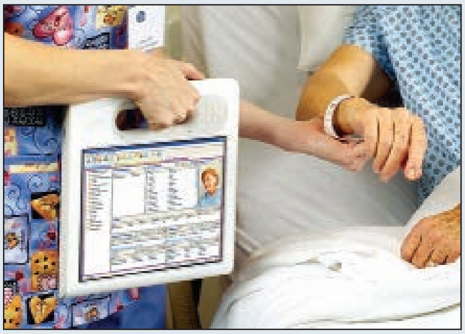
COMPUTERS AND NETWORKING

TAKE THIS TABLET WITHOUT WATER

One way to compete in the tablet PC market is to produce general-purpose machines and make a wide variety of software available. Another way is to focus on a niche market and design the hardware and software around the intended use. The latter is the approach taken by Motion Computing, Inc. (**www.motioncomputing.com**), with its C5v "point of care" unit, designed specifically for healthcare environments with partner Intel Healthcare providing the Mobile Clinical Assistant (MCA) reference architecture. Even though it's probably not part of your buying future, you might be pleased to see one in the hands of the nurse the next time you visit the local hospital, as it is designed to help "reduce transcription and medication administration errors, enhance clinician workflows, and enable more informed decisions at the point of care."

In addition to standard tablet features, it offers a built-in barcode scanner to match patients to the proper treatments, an RFID scanner to verify both patients and care providers, and an integrated digital camera that provides documentation of wounds, surgical sites, range of motion, and other info that may eventually be helpful to your malpractice lawyer. It also offers Bluetooth and Wi-Fi (and optional mobile broadband) connections for automatic uploads of vital signs and so on into medical records. You get both pen and speech input capabilities and an anti-theft security suite.

In terms of hardware, the 3 lb, ruggedized unit (MIL-STD-810G tested) features a Gorilla® Glass display, a choice of Intel Core processors, 2 GB of RAM (upgradeable to 4 GB), a 160 GB drive, and a disinfectable chassis. Plus, a hot-swap battery feature keeps the unit running. Although the price of tablet PCs has been dropping precipitously (widely estimated to be in the neighborhood of $300 by the end of this year), the C5v starts at $1,895 MSRP. But, hey, the cost will be spread out among many patients, and if it keeps you from being treated for aphagia (inability to eat) when you really have aphakia (lens missing from your eye), it will be well worth it. ▲



■ The C5v tablet PC, billed as the industry's first mobile clinical assistant.

ROK ON!

Addressing an entirely different niche is PCAudioLabs (PCAL, **www.pcaudiolabs.com**) with its Rok Box line of machines categorized as digital audio workstations. Users and endorsers include the likes of Eric Clapton (who used a PCAL system to record the 2007 Crossroads Festival DVD), the Grand Ole Opry, Alan Parsons, and even Dweezil Zappa. The hardware side of the system ranges from the MC m5 laptop to the entry-level MC 3 desktop to the flagship MC 7x, plus a rack-mount model and unique configurations from the custom shop. The MC 7x combines an Intel Core i7 processor with 16 GB of RAM and a 20 GB SSD, then adds a 500 GB program drive, a 1 TB audio/media drive, a 2 TB sample drive, and a noise-attenuated cooling system. Sure, you could get a comparable machine elsewhere, but you have to consider the software side which includes Windows 7 Pro 64-bit plus a pre-installed batch of music applications including Sonar X1 Essential (Cakewalk's music software package), Komplete 7 Elements (sound and instrument library), VielKlang Instant Harmony (for single-click creation of background choirs and brass arrangements), Xils 3se (a software synthesizer), Amplitube (guitar amp and effects package), Sampletank (sampling workstation), Nimbit (direct marketing software), and an Obedia video training package to help you put it all together. The whole thing starts at $1,699 which is a small price to pay to become the next rock deity. ▲

■ Interior of a Rok Box digital audio workstation.

COMPUTERS AND NETWORKING CONTINUED

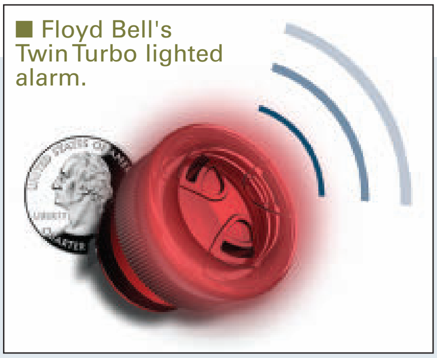
LOOK MA, NO POWER CORD

■ AOC's e2251 Fwu operates without a power cord or VGA connection.

I may as well admit it. My desk is still equipped with two monstrous CRT monitors, each taking up more desk space than a window air conditioner and drawing almost as much power. Being stuck in technological antiquity has not prevented an awareness of such radically novel devices as desktop LCD monitors, but it did come as a surprise to discover the existence of units that are so efficient that they don't even need to be plugged into the wall. One such marvel is the e2251 Fwu, a 22 in (16:9) monitor introduced at the 2012 Consumer Electronics Show (CES) in Las Vegas by AOC (**us.aoc.com**). The unit receives both power and signal via a single USB cable, providing a simple plug-and-play connection with no need for a power cord or VGA cable. Specs include a 1,000:1 contrast ratio, 5 ms response time, 16 million colors supported, 1920 x 1080 resolution at 60 Hz, and compatibility with PCs as well as Macs using the DisplayLink driver. The Energy Star-compliant unit (as of this writing) is available online for about $185. AOC, by the way, is a descendent of the Admiral TV company, founded in Chicago by Ross Siragusa in 1934. At its peak in 1951, the company sold five million sets. In 1967, it was refounded in Taiwan as Admiral Overseas Corporation. ▲

CIRCUITS AND DEVICES

ALARM COMBINES LIGHT AND SOUND



■ Floyd Bell's Twin Turbo lighted alarm.

If your project needs a panel-mount annunciator that will catch people's attention, take a look at the new Twin Turbo™ lighted alarm from Floyd Bell (**www.floydbell.com**). It is a small (1 x 1 in) piezoelectric audio alert that also emits a 180° daylight-viewable light when activated, effectively combining the company's Turbo series alarms with the Turbo Light panel indicators into a single alarm. Perhaps the most remarkable feature is that the sound output measures up to 103 dB at a distance of two inches — which is not up to the 130 dB threshold of pain, but certainly reaches the threshold of annoyance. Still, it operates in the range of 9 to 30 VDC while drawing only 50 to 110 mA. It's available in five colors and offers seven tones (siren, staccato, whoop, warble, continuous, beep, and chime). A rotary control is available to provide up to 20 dB attenuation, and the polycarbonate plastic case makes it tamper-proof per IP68 and creates a NEMA 4X seal when installed. It will set you back $29.97 in single quantities, but you don't want a wimpy alarm, do you? ▲

AVIATION UPGRADE

If you work in any completely useless profession (consultant, government bureaucrat, chief information officer, reality TV producer, Congressman, etc.), you probably make paper airplanes to pass the time. Lots of paper airplanes. Well, your thankless office drudgery is about to get more interesting, thanks to the PowerUp Electric Paper Airplane Kit which wowed the crowd at the 2012 Spielwarenmesse International Toy Fair, Nürnberg. Now, you can convert a homemade paper airplane into a free-flight electric model just by clipping on the lightweight, carbon-fiber mechanism. Best of all, it recharges for a 30 second flight in only 20 seconds, so you won't have to waste time while you're wasting time. You can obtain one from Amazon or several other Internet stores for about $20. Just fill out Requisition Form 345A-2012, submit it to the clerk at the Office of Procurement Authority (making sure that the item complies with definitions related to delegations of authority and signature authority), and forward three copies to the deputy executive assistant in the Department of Non-Complex Purchases. ▲

■ The PowerUp™ electric paper airplane kit.

CIRCUITS AND DEVICES CONTINUED

DON'T REPLACE IT — REPAIR IT

If you are faced with the replacement of PC boards with damaged circuits or worn-out contact fingers, an alternative might be one of the Micro-Metallizer pens from Hunter Products, Inc. (**www.hunterproducts.com**). The company offers a selection of systems developed specifically to "provide simple and convenient electroplating capability" for various scientific and engineering applications that also include dental work, artwork, and other restoration projects. Preloaded pens are available for laying down a selection of metals including gold alloys, nickel, black nickel, silver, tin, copper, and others. Power can be supplied by any variable DC supply providing up to 12V at 0.1A, or you can buy one from Hunter. If all you need is to repair some contact points, you can probably get by with the PL1000C Contact Repair Kit which comes in at $360, including three pens: absorbent, nickel, and 24K gold. For bigger jobs, you may need the PL1000HD Heavy Duty Kit which will run you $810, but comes with absorbent, heavy silver, heavy copper, heavy 24K gold, heavy nickel, and rhodium pens. Additional metallizing pens go for $48 for copper up to $118 for gold, and $269 if you're unfortunate enough to need rhodium. ▲

INDUSTRY AND THE PROFESSION

NAE'S DRAPER PRIZE AWARDED

At a gala Washington, DC dinner last February, the National Academy of Engineering (**www.nae.edu**) presented its Charles Stark Draper Prize to T. Peter Brody, George H. Heilmeier, Wolfgang Helfrich, and Martin Schadt for "the engineering development of the liquid crystal display (LCD) that is utilized in billions of consumer and professional devices." Heilmeier discovered the dynamic scattering mode (DSM) which resulted in the first operational LCD, and Helfrich and Schadt invented the twisted nematic (TN) field effect of liquid crystal displays. Brody created the active matrix (AM) drive which enabled an array of new capabilities for LCDs. The annual award — which includes a $500,000 swag — was created to honor engineers "whose accomplishments have significantly benefited society." It was created to honor the memory of "Doc" Draper, known as the "father of inertial navigation." **NV**

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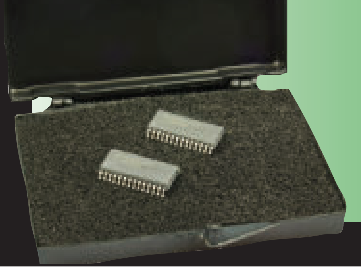

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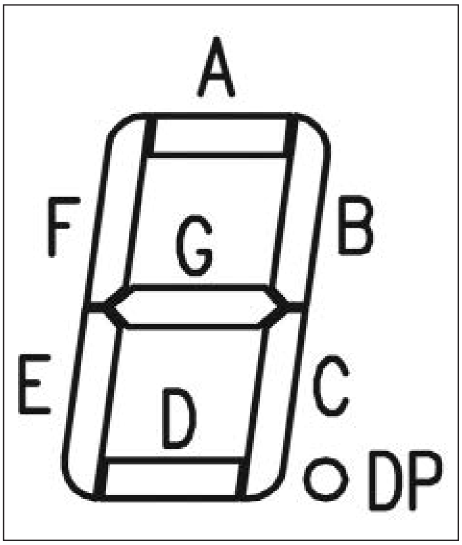
BY RON HACKETT

DEVELOPING SOFTWARE FOR THE LED-2x7 PROJECT BOARD

In the previous installment of the PICAXE Primer, we covered the design and construction of a 20M2-based two-digit seven-segment LED display board. This month, we're going to focus on two aspects of software development for our LED-2x7 board. First, we'll discuss how we can use software to help us "untangle" the illogical connections to the LED display segments that were necessary to simplify our stripboard layout. Next, we'll use the 20M2's new *time* variable to implement an accurate second counter.

In the next installment of the Primer, we'll use an inexpensive TV remote control to implement a flexible user input function. Then, we'll see how simple it is to take accurate temperature readings with the DS18B20 temperature sensor, and how we can also measure the internal temperature of the 20M2 processor. But first, we need to make sense of our illogical stripboard wiring.

FIGURE 1. Standard labels for a seven-segment LED display.



USING SOFTWARE TO UNTANGLE OUR I/O CONNECTIONS TO THE LED DISPLAY

Figure 1 (which was also included in the previous column) presents the standard labels for each of the segments of a seven-segment display. It's reprinted this month so that you can easily refer to it during the following discussion.

Figure 2 summarizes the output connections that we need to untangle. If you want to check those connections, you can refer back to the circuit schematic in the previous installment. As we already know, the connections are far from logical. In order to display a single digit, we need to light specific LED segments that are connected to both port C and port B. In addition, displaying any specific digit on each of the two seven-segment displays involves a completely different set of output pins. For example, to display the digit "1" we need to light LED segments B and C (see **Figure 1**). Therefore, to display 1 on LED 1 (the ten's digit), we need pins B.2 and C.0 to be at a high level and all other pins to be at a low level.

FIGURE 2. Connections between 20M2 output pins and LED segments.

LED 1 (Ten's Digit)

I/O Pin	Segment
B.1	A
B.2	B
C.0	C
C.5	D
B.4	E
B.3	F
B.0	G

LED 2 (One's Digit)

I/O Pin	Segment
B.6	A
B.7	B
C.1	C
C.3	D
C.4	E
B.5	F
C.2	G

	LED 1 (Ten's Digit)		LED 2 (One's Digit)	
Port:	PinsC	PinsB	PinsC	PinsB
Pin:	76543210	76543210	76543210	76543210
Segments:	xxDxxxxC	xxxEFBAG	xxxEDGCx	BAFxxxxx
Display 0	%00100001	%00011110	%00011010	%11100000
Display 1	%00000001	%00000100	%00000010	%10000000
Display 2	%00100000	%00010111	%00011100	%11000000

■ FIGURE 3. Data definitions necessary to display integers 1, 2, and 3.

However, to display 1 on LED 2 (the one's digit), we need pins B.7 and C.1 to be at a high level and all other pins to be at a low level. Of course, if we wanted to display "11" we would need all four of those pins to be high and all the other pins to be low.

In general, for each digit we want to display we need to define two bytes (one for the port B pins and one for the port C pins) for displaying the digit on LED 1 (ten's digit), and two more bytes for displaying it on LED 2 (one's digit). That means we need a total of 40 data bytes in order to represent the digits 0 through 9.

Figure 3 presents the 12 data bytes that we need to display the first three digits (0, 1, and 2). In order to understand how I arrived at the data in **Figure 3**, let's examine the four bytes that are needed to display the digit 1 on LED 1 and LED 2. Before we do that, however, take a look at the row in **Figure 3** that's labeled "Segments:" — it contains all the connection data that was presented earlier in **Figure 2**, but this time the same connections are displayed in a way that makes it easier to understand the data bytes contained in the figure.

For example, the "D" in the first "PinsC" column of the Segments: row is directly below the "5" in the "Pin:" row. This tells us that (for LED 1) segment D connects to pin C.5 which is what was shown earlier in **Figure 2**. If you examine the positions of the remaining 13 LED segments, you will see that they all match the information presented in a different format in **Figure 2**.

Finally, each "x" in the Segment: row of **Figure 3** indicates that there is no pin-to-segment connection at that position for the specified LED. We can simply place a "0" in that position for each of our data bytes.

Okay. Now that we understand the structure of **Figure 3**, let's take a closer look at the two data bytes that are needed to display the digit 1 on LED 1. Earlier, we saw that we needed to raise the voltage level on pins B.2 and C.0 in order to display 1 on LED 1. If you look at the two data bytes for displaying that 1, you can see that I have placed a 1 in the two bit positions that correspond to pin B.2 (LED 1, segment B) and pin C.0 (LED 1, segment C). If you examine the two data bytes for displaying 1 on LED 2, you will be able to see the analogous correspondence to the data presented earlier in **Figure 2**.

By now, I'm sure you've had more than enough discussion of data structures, so let's move on to our first program and see how all this theory can actually be useful. We will be experimenting with two programs this month. Both of them (*LED-2x7count.bas* and *LED-2x7time.bas*) are available for downloading from the article link. Now would be a good time to download the two programs and print out copies for reference. You may also want to take a break at this point, before we delve into some of the details of the first program.

COUNTING FROM 0 TO 99

In our first program (*LED-2x7count.bas*), we're going to use everything we have discussed thus far to implement a simple count from 0 to 99. There are several points about the program that need to be clarified, but I'm sure you will want to try it out before getting into any more theoretical discussion. Before you run the program, make sure that the two-pin shunt on the LED-2x7 stripboard is in the correct position to enable the discrete LED that's connected to pin A.0.

When you're ready to get back to work, the following are more thorough comments for the program. As we have done in the past, the number of each comment refers to the corresponding number at the right-hand edge of the program listing.

[1] In the **Variables** section, I have broken a rule (which we have discussed before) by defining a word variable (*symbol segsLED = w0*) and also defining either or both of the two bytes (b0 and b1) that the word variable comprises. Usually, this will get us into trouble because changing the value of one of the three variables (in this case, w0, b0, or b1) will also change the value of one or both of the other two variables. However, sometimes that's exactly what we want to do, and this is one of those times. (We'll discuss this further in comment #4, below.)

However, there was an unexpected complication in my little scheme. When I first wrote this program, "garbage" appeared on the LED display, not the orderly count that I expected. After a typically frustrating debugging process, I discovered the cause of the problem. The standard way that the PICAXE compiler uses to store a word variable is generally referred to as "big endian" which means that the high byte of the word is stored before the low byte (i.e., w0 = b1:b0). However — for some reason — when the *read* command reads a word variable, it is "little endian" which means that the low byte is retrieved/saved before the high byte. Once I became aware of this little

Bit A	Bit B	A OR B
0	0	0
0	1	1
1	0	1
1	1	1

■ FIGURE 4. Truth table for the digital OR function.

■ FIGURE 5. Results of the digital OR for the value 73.

	segsC	segsB
digTen = 7	%00000001	%00000110
digOne = 3	%00001110	%11000000
digOne OR digTen	%00001111	%11000110

anomaly, it was a simple matter to reverse the definitions of the *segsC* and *segsB* variables so that they are in the necessary little endian order for the *read* statement; the result was that the garbage disappeared, and the count proceeded correctly.

[2] In the **Directives** section, the *#no_data* directive is commented out. Therefore, the first time you download the program to your LED-2x7 board, the EEPROM data will also be downloaded. Of course, once the EEPROM data is installed in the 20M2, it's more or less permanent (at least for 10 years or so), so you may want to "un-comment" the *#no_data* directive after the initial download, so that time isn't spent re-downloading the same data every subsequent time you modify and re-download the program.

[3] In the **Data** section, the first three *data* statements in each of the two subsections contain the same information that we discussed earlier for digits 0 through 2, and the remaining *data* statements define the necessary values for the other seven digits. Since each *data* statement contains two bytes, it's necessary for the *data* addresses to all be multiples of two. When I first wrote the program, I started the *data* statements for LED 1 (the ten's digit) at location 20, but I soon realized that I might want to add additional *data* definitions (e.g., for a blank digit, a dash, etc.), so I changed the LED 1 data so that it begins at location 50; this allows more than enough room for any additional data definitions that may be needed.

[4] In the **displayValue subroutine**, we first get the value of the one's digit of the number that we are going to display by using modular arithmetic to compute the remainder of a division by 10. (For example, 73 // 10 returns the remainder of the division [i.e., 3] which is the one's digit.) Next, we double the value of the remainder that we just computed. This is necessary because we have stored two *data* bytes for each digit we want to display.

For example, in order to retrieve the correct two *data* bytes for the digit 3, we need to begin accessing the data at location 6. (Refer to the *data* definitions in the program listing.) Once we have determined the correct starting location for the two bytes of data that we want to retrieve, we can simultaneously read both bytes and store them in a single word variable by including the keyword *word* in the *read* statement. In our example, we would read the two *data* bytes that contain the segment values for displaying a one's digit of "3" on LED 2 (*data* locations 6 and 7) as a single *word* variable (*digOne*).

At this point, we have stored the correct LED segment values for displaying the one's digit, so we repeat a similar process to obtain the LED segment values for the ten's digit of the number we want to display. However, this time we want the quotient of the division by 10 which will give us the ten's digit we need. In our example, 73 / 10 = 7 (in integer arithmetic).

As we did with the one's digit, we again double the value of the ten's digit, but this time we also need to add 50 in order to retrieve the correct two data bytes for the ten's digit. Again, in our example, 2 * 7 + 50 = 64 which is the *data* location for the first of the two *data* bytes that define the LED segment values for a ten's digit of 7.

Next, we need to combine the two values we just computed (*digOne* and *digTen*) so that we can correctly light all the necessary LED segments to display our two-digit number. For this purpose, we're using the PICAXE "OR" function which performs a bit-wise digital OR on the two 16-bit values we have just computed. If you're not familiar with the digital OR function, its truth table is presented in **Figure 4**.

If you prefer English: Bit A OR B = 1 if A = 1 or B = 1 or if both A and B = 1. Bit A OR B = 0 if both A and B = 0. In order to see how this works in the program, **Figure 5** summarizes the data for our example of displaying the value 73. As you can see, the result of the digital OR indicates that we will need to light a total of eight segments (four via port B and four via port C) to display the value 73 on the LEDs.

Finally, the result of the digital OR is assigned to the word variable *segsLED*. At this point, it's important to remember that — as we discussed in comment #1 — updating *segsLED* also automatically updates the two byte variables *segsB* and *segsC*. As a result, we can now simply assign *segsB* to *outpinsB*, and *segsC* to *outpinsC*, which displays "73" on the LED.

At this point, you're probably beginning to feel a little overloaded with theory. If so, I can assure you that the worst is over. Our second program this month (*LED-2x7time.bas*) uses the same basic structure as *LED-2x7count.bas* with a couple of minor modifications that really aren't very complicated at all. So, when you understand how *LED-2x7count.bas* functions, take a break, be brave, and forge ahead!

IMPLEMENTING AN ACCURATE TIMER

Now that we have our LED-2x7 counting properly, the next logical step is to modify our program so that the count advances at precisely one count per second. The *wait 1* instruction in the counting program already gets us close to one count per second, but it's not very precise because there are two other instructions in the main *do/loop*, as well as the loop itself. Of course, these additional instructions also require a little time to execute, so our counter is actually advancing slightly slower than one count per second.

As usual, there's more than one way to implement an accurate second counter. One possibility would be to slightly decrease the length of the delay in the main *do/loop*. For example, we could replace the *wait 1* instruction with *pause 975*. However, we would need an accurate way to measure the results, and there would be a fair amount of trial and error before we got it right.

Out of curiosity, I actually tried that approach, and found that *pause 983* counted from 0 to 99 seconds with a total error of about 0.3 seconds (which would be plenty accurate for my purposes). However, every time I modified the program to add or change features, I would need to repeat the trial and error process to adjust the *pause* parameter for timing accuracy.

Of course, there is a better way; we can use the 20M2's built-in *time* variable to implement a reasonably accurate second counter. *Time* is a word variable, so it increments from 0 to 65,535 seconds (then rolls over to 0) which is a little more than 18 hours. (Of course, we don't have to worry about the roll-over for our little 99 second counter.) Because the *time* variable is built in, there's no need to declare it in the variables section; in fact, doing so will result in a syntax error ("Error: Symbol is already defined!").

Processor Speed (MHz)	4	8	16	32
Time Increments (Secs.)	1.0	2.0	1.0	0.5

■ FIGURE 6. Processor speed vs. time increments.

The beauty of the *time* variable is that it automatically increments once per second, as long as the processor is running at either 4 MHz or 16 MHz. At other processor speeds, the situation is more complicated. **Figure 6** summarizes increment intervals for the *time* variable at the four most frequently used processor speeds. (I haven't tested the *time* variable at any other processor speed.) As you can see, life is easier if we just stick to either 4 MHz or 16 MHz whenever we want to use the *time* variable in a program.

It's important to note that the *time* variable is more than accurate enough for reasonably short time periods, but for long time periods (days, weeks, etc.) the error does add up. (We'll do the math when we actually run the program.)

So, let's see how we can modify our counting program to more accurately count seconds. Fortunately, all the declarations (constants, variables, etc.) that we will need are exactly the same as they were in the first counting program. In addition, I structured the counting program so that its *displayValue* subroutine can also remain the same. Consequently, all we need to do is rewrite our main program loop, so let's take a closer look at that portion of the modified program (*LED-2x7time.bas*):

```
do
  time = 0
  do
    toggle A.0
    value = time
    nextSec = value + 1
    gosub displayValue
    tarry: if nextSec >
    time then tarry
  loop until time = 100
loop
```

As you can see, the main program consists of two nested *do/loops*. The outer loop simply initializes *time* to 0 and then executes the inner loop, so let's focus on that portion of the code. The initial *toggle* instruction is included just for debugging and timing the loop. Next, we assign the current value of *time* to the *value* variable, and then set *nextSec* equal to value + 1. Therefore, the first time through the loop, at this point *value* = 0 and *nextSec* = 1. Now, we execute the *displayValue* subroutine which displays "00" on the LEDs (because *value* = 0).

The next statement is the heart of the main program. It begins with an address (*tarry:*) and executes a simple *if/then* statement. As long as *nextSec* is greater than *time*, this statement just keeps looping around within itself. However, don't forget that *time* is automatically incrementing in the background.

As soon as one second has elapsed, *time* automatically becomes 1, so *nextSec* (which is currently also 1) is no longer greater than *time*. As a result, the program moves on to the final statement in the inner *do/loop* which checks to see if *time* has reached a value of 100; if not, the inner *do/loop* is executed again.

The second time through the inner loop, *value* = 1 (because *time* is now 1), *nextSec* = 2, "01" is displayed on the LEDs, and then the program again loops at the "*tarry:*" address until *time* automatically increments. And so it goes, until *time* = 100.

At that point, the inner *do/loop* terminates and the outer *do/loop* executes again, resetting *time* to 0 and repeating the entire count. Finally, note that we never attempt to display "100" on our two-digit LED display; as soon as *time* = 100, the inner *do/loop* terminates without calling the displayValue subroutine.

Now that we understand how

LED-2x7time.bas functions, it's time to download it to the LED-2x7 and run it. The display may not seem to increment at a rate that's very different from our original counting program, but it is a much more accurate second counter.

To determine the accuracy, I used my digital logic probe (which operates on a very accurate timebase) to measure the length of the pulses that are sent to the discrete LED on pin A.0. The time required to toggle pin A.0 60 times should be exactly 60 seconds; the actual waveform measured at 59.97 seconds.

Initially, I was impressed but when I did the math, I realized that an error of 0.03 sec/min adds up quickly (to 1.8 sec/hr, or 43.2 sec/day, or 302.4 sec/week, etc.). If you have an accurate means of measuring your project's timing, your figures should be close. However, they probably won't be exactly the same as mine due to minor variations in operating speed among individual processors. In any case, you probably won't want to use an M2 processor as a real time clock.

However, for relatively brief timing — such as my espresso shot-timer project — an error of 0.03 sec/min is very acceptable. On the other hand, for long-term timekeeping purposes, an error of five minutes per week is probably unacceptable; a real time clock chip would be a much better choice. (An accurate real time clock project is on my to-do list for the Primer; we'll get to it before long.)

WHAT'S NEXT?

We're out of space this month, but we still have more features of the LED-2x7 board to explore in the next installment of the Primer:

- Using an IR TV Remote for User Input to a Running Program
- Measuring External Temperature with the DS18B20
- Taking the 20M2's Internal Temperature
- Creating a Stand-Alone Serial Output Device for Our Projects

We have already covered IR input in previous installments of the Primer (Oct and Dec '08, Feb '09, Aug '10), so we won't rehash all the details next time. In the interim, you may want to review the relevant Primer installments. Also, if you have a copy of *PICAXE Projects for the Evil Genius*, Chapter 8 focuses on the use of a TV remote with M2-class processors.

Finally, you may know by now that Panasonic has discontinued the PNA4602 IR input device that we have used in all our earlier projects, so we will need to discuss suitable pin-compatible replacements for the PNA4602.

See you next time. **NV**

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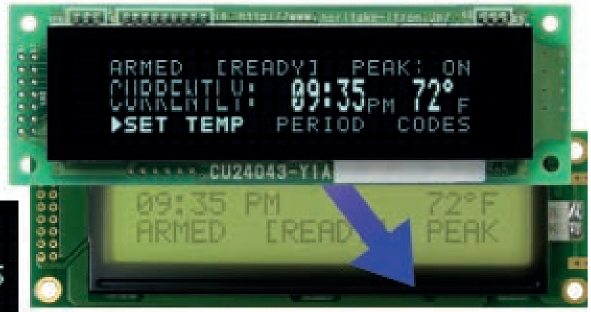

24x4 VFD on 20x2 LCD

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```
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▶ALL OFF
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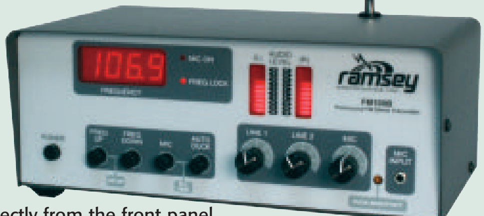
Super-Pro FM Stereo Radio Station



- ✔ **PLL synthesized for drift-free operation**
- ✔ **Built-in mixer - 2 line inputs and one microphone input, line level monitor output!**
- ✔ **Frequency range 88.0 to 108.0, 100 kHz steps**
- ✔ **Precision active low-pass "brick wall" audio filter!**
- ✔ **Dual LED bar graph audio level meters!**
- ✔ **Automatic adjustable microphone ducking!**
- ✔ **Easy to build through-hole design!**

This professional synthesized transmitter is adjustable directly from the front panel with a large LED digital readout of the operating frequency. Just enter the setup mode and set your frequency. Once selected and locked you are assured of a rock stable carrier with zero drift. The power output is continuously adjustable throughout the power range of the model selected. In addition, a new layer of anti-static protection for the final RF amplifier stage and audio inputs has been added to protect you from sudden static and power surges.

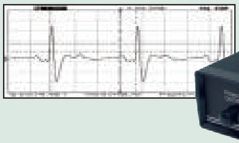
Audio quality is equally impressive. A precision active low-pass brick wall audio filter and peak level limiters give your signal maximum "punch" while preventing overmodulation. Two sets of rear panel stereo line level inputs are provided with front panel level control for both. Standard unbalanced "RCA" line inputs are used to make it simple to connect to the audio output of your computer, MP3 player, DVD player, cassette deck or any other consumer audio source. Get even more creative and use our BS2 Bullshooter-II (see our website or catalog) for digital storage and playback of announcements and ID's! In addition to the line level inputs, there is a separate front panel microphone input. All three inputs have independent level controls eliminating the need for a separate audio mixer! Just pot-up the source control when ready, and cross fade to the 2nd line input or mic! It's that simple! In addition to the dual stereo line inputs, a stereo monitor output is provided. This is perfect to drive studio monitors or local in-house PA systems.

The FM100B series includes an attractive metal case, whip antenna and built in 110/220VAC power supply. A BNC connector is also provided for an external antenna. Check out our Tru-Match FM antenna kit, for the perfect mate to the FM100B transmitter. We also offer a high power kit as well as an export-only assembled version that provides a variable RF output power up to 1 watt. The 1 watt unit must utilize an external antenna properly matched to the operating frequency to maintain a proper VSWR to protect the transmitter.

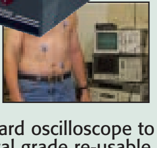
(Note: The FM100B and FM100BEX are do-it-yourself learning kits that you assemble. The end user is responsible for complying with all FCC rules & regulations within the US or any regulations of their respective governing body. The FM100BWT is for export use and can only be shipped to locations outside the continental US, valid APO/FPO addresses or valid customs brokers for documented end delivery outside the continental US).

FM100B	**Super-Pro FM Stereo Radio Station Kit, 0-25mW**	**$269.95**
FM100BEX	**Super-Pro FM Stereo Radio Station Kit, 5uW to 1W**	**$349.95**

Electrocardiogram ECG Heart Monitor



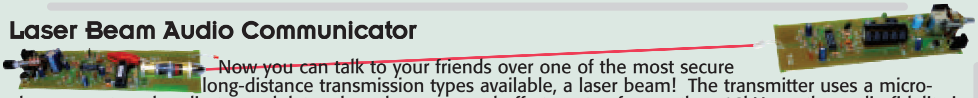
- ✔ **Visible and audible display of your heart rhythm!**
- ✔ **Bright LED "Beat" indicator for easy viewing!**
- ✔ **Re-usable hospital grade sensors included!**
- ✔ **Monitor output for professional scope display**
- ✔ **Simple and safe 9V battery operation**



Use the ECG1C to astound your physician with your knowledge of ECG/EKG systems. Enjoy learning about the inner workings of the heart while, at the same time, covering the stage-by-stage electronic circuit theory used in the kit to monitor it. The documentation with the ECG1C covers everything from the circuit description of the kit to the circuit description of the heart! Multiple "beat" indicators include a bright front panel LED that flashes with the actions of the heart along with an adjustable level audio speaker output that supports both mono and stereo hook-ups. In addition, a monitor output is provided to any standard oscilloscope to view the traditional style ECG/EKG waveforms just like you see on ER... or in the ER! 10 hospital grade re-usable probe patches are included together with the matching custom case set shown. Safe 9V battery operation.

ECG1C	**Electrocardiogram Heart Monitor Kit With Case & Patches**	**$44.95**
ECG1WT	**Electrocardiogram Heart Monitor, Factory Assembled & Tested**	**$89.95**
ECGP10	**Electrocardiogram Re-Usable Probe Patches, 10-Pack**	**$7.95**

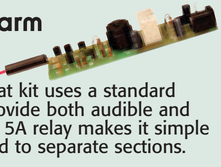
Laser Beam Audio Communicator



Now you can talk to your friends over one of the most secure long-distance transmission types available, a laser beam! The transmitter uses a microphone or external audio to modulate a laser beam on and off at a rate of more than 16kHz so the audio fidelity is much better than that of a standard 3kHz telephone line! The receiver includes filtering to remove the 16kHz carrier and leave behind the high quality audio, and then boost its level for use with earphones. Transmitter audio AGC keeps your level perfect! Includes transmitter, receiver and laser pointer. Each runs on a 9V battery.

LBC6K	**Laser Beam Audio Communicator Kit**	**$59.95**

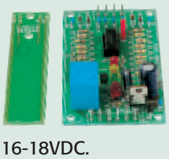
Laser Trip Senser Alarm



True laser protects over 500 yards! At last within the reach of the hobbyist, this neat kit uses a standard laser pointer (included) to provide both audible and visual alert of a broken path. 5A relay makes it simple to interface! Breakaway board to separate sections.

LTS1	**Laser Trip Sensor Alarm Kit**	**$29.95**

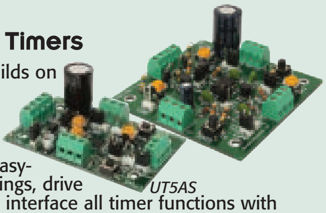
Liquid Level Controller



Not just an alarm, but gives you a LED display of low, middle, or high levels! You can also set it to sound an alarm at the high or low condition. Provides a 2A 240VAC rated relay output. Runs on 12-14VAC or 16-18VDC.

K2639	**Liquid Level Controller Kit**	**$21.95**

Ultimate 555 Timers



UT5AS

This new series builds on the classic UT5 kit, but takes it to a whole new level! You can configure it on the fly with easy-to-use jumper settings, drive relays, and directly interface all timer functions with onboard controls or external signals.

All connections are easily made though terminal blocks. Plus, we've replaced the ceramic capacitor of other timer kits with a Mylar capacitor which keeps your timings stable over a much wider range of voltages! Available in through hole or surface mount versions! Visit www.ramseykits.com for version details.

UT5A	**Through Hole 555 Timer/Osc Kit**	**$24.95**
UT5AS	**SMT 555 Timer/Osc Kit**	**$26.95**

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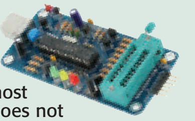

Finally, a compact USB PIC Programmer with a 20 pin ZIF socket for easy programming of most Microchip PIC Flash devices that does not require low voltage programming. Plus it uses USB therefore no more RS232 compatibility blues!

CK1301	**USB PIC Programmer Kit**	**$34.95**

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Track down jammers and hidden transmitters with ease! 22.5 degree bearing indicator with adjustable damping, phase inversion, scan and more. Includes 5 piece antenna kit. Runs on 12VDC vehicle or battery power.

DDF1	**Doppler Direction Finder Kit**	**$169.95**

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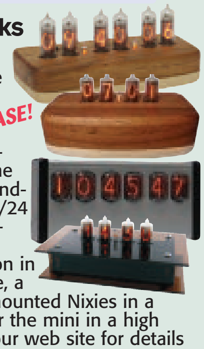

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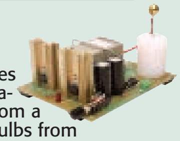
NIXIE	**Nixie Tube Clock Kits**	**from $139.95**

HV Plasma Generator



Generate 2" sparks to a handheld screwdriver! Light fluorescent tubes without wires! This plasma generator creates up to 25kV at 20kHz from a solid state circuit! Build plasma bulbs from regular bulbs and more! Runs on 16VAC or 5-24VDC.

PG13	**HV Plasma Generator Kit**	**$64.95**

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Need to "perk-up" your counter or other equipment to read weak signals? This preamp has low noise and yet provides 25dB gain from 1MHz to well over 1GHz. Output can reach 100mW! Runs on 12 volts AC or DC or the included 110VAC PS. Assmb.

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The handiest item for your bench! Includes a RoHS compliant temp controlled soldering station, digital multimeter, and a regulated lab power supply! All in one small unit for your bench! It can't be beat!

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Testing your system is easy. To test the complete key fob-to-vehicle and vehicle-to-key fob communications path just stand close to the vehicle with the WCT3 and your key fob in hand. Press the test button and the WCT3 will detect and display the presence of the vehicle's 125kHz/20KHz signal and, if they "handshake", will also detect and display the presence of your key fob's 315MHz return signal. You can independently test key fob only signals (panic, lock, trunk, etc.) by holding the key fob near the WCT3, pressing the test button, and pushing the function button on the key fob. The same functionality testing can be done with IR key fobs. The modulated IR signal is detected and will illuminate the IR test LED on the test set. If you know a few "secrets" you can also see if the tire pressure sensors/transmitters are generating signals or the built-in garage door opener in your rear view mirror is transmitting a signal! But the WCT3's uses go beyond the automotive world. The majority of building wireless access systems also utilize 125 kHz. Just hold the test set near the building access sensor and the WCT3 will detect the 125 kHz signal. That will help you troubleshoot door access locations that are not working. It gets even better... you can use the WCT3 to test virtually any other 315 MHz, 433 MHz, 125kHz, 20kHz and IR wireless control system to verify generation of a signal. The WCT3 test set is housed in a compact 2.25" x 4.6" x 9" case and is powered by a standard 9VDC battery (not included).

WCT3 Four Mode Keyless Entry Test Set Kit $59.95

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The hit of the decade! Our patented receiver hears the entire aircraft band without any tuning! Passive design has no LO, therefore can be used on board aircraft! Perfect for airshows, hears the active traffic as it happens! Available kit or factory assembled.

ABM1 Passive Aircraft Receiver Kit $89.95

RF Preamplifier

The famous RF preamp that's been written up in the radio & electronics magazines! This super broadband preamp covers 100 KHz to 1000 MHz! Unconditionally stable gain is greater than 16dB while noise is less than 4dB! 50-75 ohm input. Runs on 12-15 VDC.

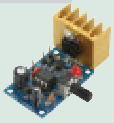
SA7 RF Preamp Kit $19.95

Mad Blaster Warble Alarm

If you need to simply get attention, the "Mad Blaster" is the answer, producing a LOUD ear shattering raucous racket! Super for car and home alarms as well. Drives any speaker. Runs on 9-12VDC.

MB1 Mad Blaster Warble Alarm Kit $9.95

PWM Motor Controller



This handy controller uses a pulse width modulated output to control the speed of a motor without sacrificing torque! Handles a continuous current of 5A and includes LED to indicate speed as well as an oversized gold heatsink! Also available factory assembled.

CK1102 5A PWM Motor Controller Kit $14.95

Air Blasting Ion Generator

Generates negative ions along with a hefty blast of fresh air, all without any noise! The steady state DC voltage generates 7.5kV DC negative at 400uA, and that's LOTS of ions! Includes 7 wind tubes for max air! Runs on 12-15VDC.

IG7 Ion Generator Kit $64.95

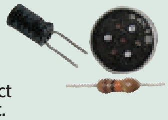
Tri-Field Meter Kit

THE GHOST DETECTOR!

"See" electrical, magnetic, and RF fields as a graphical LED display on the front panel! Use it to detect these fields in your house, find RF sources, you name it. Featured on CBS's Ghost Whisperer to detect the presence of ghosts! Req's 4 AAA batteries.

TFM3C Tri-Field Meter Kit $74.95

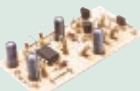
Electret Condenser Mic



This extremely sensitive 3/8" mic has a built-in FET preamplifier! It's a great replacement mic, or a perfect answer to add a mic to your project. Powered by 3-15VDC, and we even include coupling cap and a current limiting resistor! Extremely popular!

MC1 Mini Electret Condenser Mic Kit $3.95

Voice Activated Switch



Voice activated (VOX) provides a switched output when it hears a sound. Great for a hands free PTT switch or to turn on a recorder or light! Directly switches relays or low voltage loads up to 100mA. Runs on 6-12 VDC.

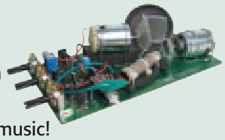
VS1 Voice Switch Kit $9.95

Touch Switch

Touch on, touch off, or momentary touch hold, it's your choice with this little kit! Uses CMOS technology. Actually includes TWO totally separate touch circuits on the board! Drives any low voltage load up to 100mA. Runs on 6-12 VDC.

TS1 Touch Switch Kit $9.95

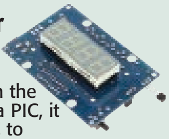
Laser Light Show



Just like the big concerts, you can impress your friends with your own laser light show! Audio input modulates the laser display to your favorite music! Adjustable pattern & speed. Runs on 6-12VDC.

LLS1 Laser Light Show Kit $49.95

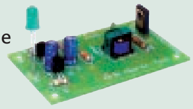
Digital LED Thermometer



This handy thermometer reads Celsius or Fahrenheit on an eye-catching .56" LED display! Based on the DS18B20 sensor and controlled by a PIC, it has a range of -67°F to 257°F (-55°C to 125°C) with a wired remote range of 325 feet!

CK127 Digital LED Thermometer Kit $29.95

Tickle-Stick Shocker



The kit has a pulsing 80 volt tickle output and a mischievous blinking LED. And who can resist a blinking light and an unlabeled switch! Great fun for your desk, "Hey, I told you not to touch!" Runs on 3-6 VDC.

TS4 Tickle Stick Kit $9.95

Speedy Speed Radar

Speed readout is on two LED displays which can be set accurately (better than 1%) to show MPH, kilometers-per-hour, or even feet-per-second. An earphone output allows you to hear the actual Doppler frequency shift of moving objects, the theory upon which all radars operate.

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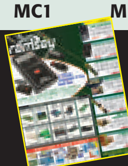

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Q&A

WITH RUSSELL KINCAID

In this column, I answer questions about all aspects of electronics, including computer hardware, software, circuits, electronic theory, troubleshooting, and anything else of interest to the hobbyist. Feel free to participate with your questions, comments, or suggestions. **Send all questions and comments to:** **Q&A@nutsvolts.com**

WHAT'S UP:

Join us as we delve into the basics of electronics as applied to every day problems, like:

- ✓ **Lighthouse Lamp**
- ✓ **PCMCIA Memory Card**
- ✓ **Multi-Station Intercom**

LED FLASHER CIRCUIT

Q I want to make an LED flasher with 300 pieces of 5 mm red LEDs, preferably with an adjustable pot for speed control (flashing time). I have three words (FATURA ÖDEME NOKTASI); the LEDs are in series in each word and the three words are parallel.

— Selahattin Sadoglu

A I count 92 LEDs in word #1; 93 in word #2; and 107 in word #3. Since the numbers are not equal, it will be necessary to put a resistance in series. Each LED drops about two volts, so word #3 will need 214 volts and 1.8K; one watt in series with the other words will make all the currents more or less equal. The LEDs are rated 20 mA but I don't recommend operating at max, so make the current 16 mA times three equals 48 mA; the power required is 10.3 watts.

I recommend a DC/DC boost circuit like **Figure 1**. I used the formulas from the LM5022 datasheet to generate the values. If you want to use these equations for another design, I should point out that the equation for Rt on page 9 is screwed up. That equation should be:

$$Rt = (1-8*10^{(-8*fsw)})/(fsw*5.77*10^{(-11)})$$

Also, how to compute R1, C2, and C1 needs explanation. The gain equation:

$$Aps = (1-D)*Ro/(2*Rsns)$$

where D = duty cycle, Ro = output resistance, and Rsns = current sense, gives the gain in volts/volt but you will need it in dB for the next step: dB=20* LOG(V/V). Since GWBASIC only does natural logarithms, I use dB = 8.686* LN(V/V). From the low frequency pole:

$$F1=1/(PI*(Ro+ESR)*Co)$$

where PI = 3.14, ESR = resistance of Co, and Co = output cap.

On semilog paper, draw a line at -40 dB per decade past 0 dB. At about 20 dB on this line, draw a line at -20 dB per decade past 0 dB. The starting point is F2. Starting at about -6 dB on this line, continue at -40 db/decade; this is F3.

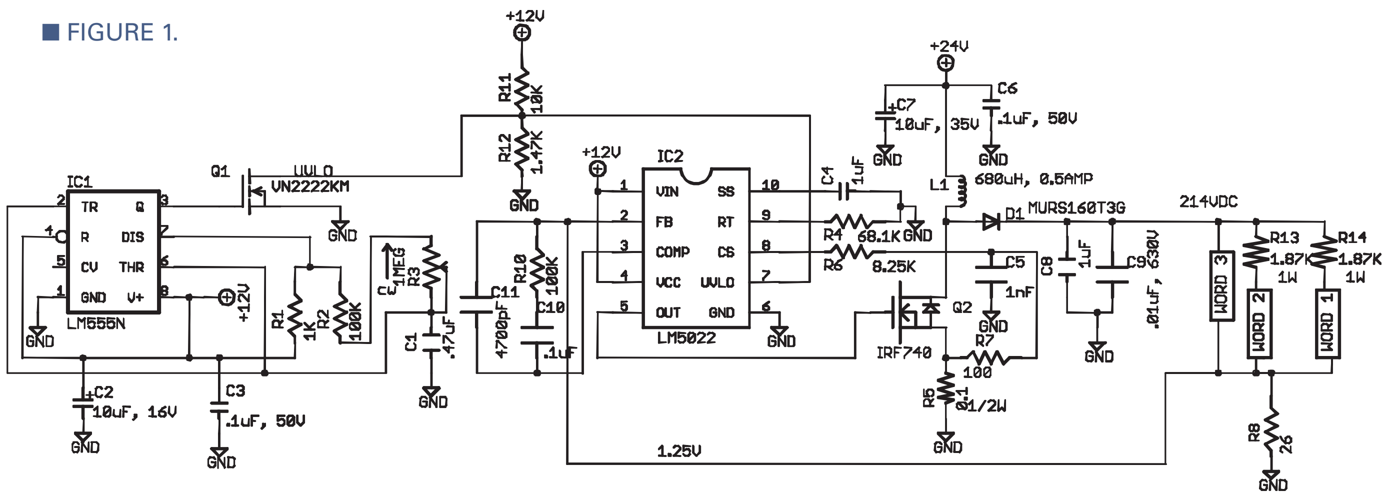
Now, choose a convenient value for C2, then R1 = 1/2/PI/F2/C2 and C1 = 1/2/PI/F3/R1.

The UVLO pin can be pulled to ground to turn the supply off and blink the LEDs. The RC of the 555 timer is calculated to vary from 1.5 blinks per second to 15. The blink rate can be reduced by increasing C1.

LIGHTHOUSE LAMP

Q I am building a five foot tall lighthouse for my front garden. I need a circuit that will light a dozen or so 5 mm white LEDs. The LEDs need to

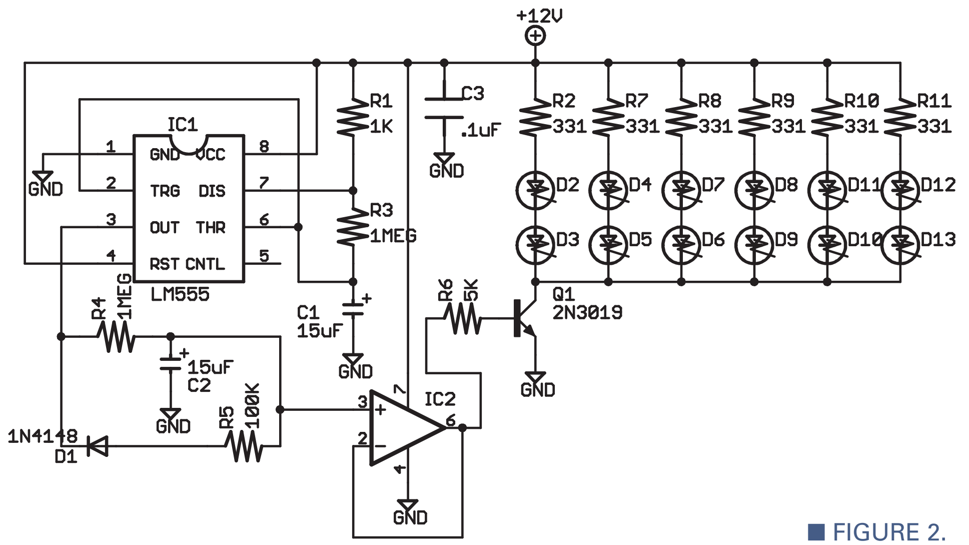
■ FIGURE 1.


+12V
R11
10K
R12
1.47K
GND
IC1
TR
Q
R
DIS
CV
THR
GND
V+
LM555N
Q1
UVLO
VN2222KM
+12V
R1
1K
R2
100K
1MEG
R3
C1
.47uF
C2
10uF, 16V
C3
.1uF, 50V
C11
4700pF
R10
100K
C10
.1uF
IC2
VIN
FB
COMP
VCC
OUT
SS
RT
CS
UVLO
GND
LM5022
1.25V
+24V
C7
10uF, 35V
C6
.1uF, 50V
C4
1uF
L1
680uH, 0.5AMP
R4
68.1K
R6
8.25K
D1
MURS160T3G
C5
1nF
Q2
IRF740
R7
100
R5
0.1
1/2W
C8
1uF
C9
.01uF, 630V
214VDC
R13
1.87K
1W
R14
1.87K
1W
WORD 3
WORD 2
WORD 1
R8
26
GND

slowly come up to full brilliancy over a period of a second or so, stay at full brilliancy for three or four seconds, then slowly decline to darkness over a period of a second or so, stay dark for a period of three seconds, and begin the cycle again.

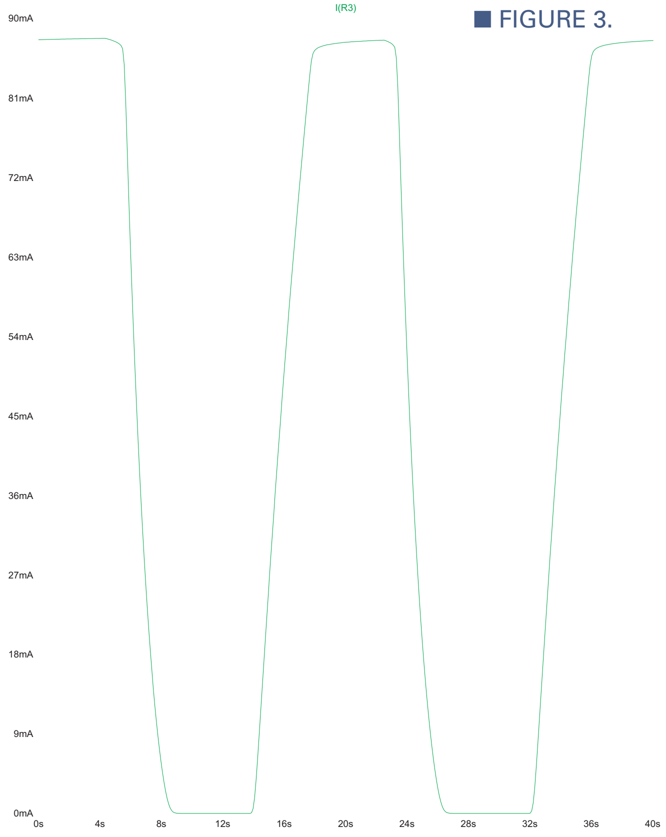
I expect to power these with a 12 volt gel cell charged by solar cells with a governor. Do you have such a circuit in your bag of tricks?

— Ed Taylor



■ FIGURE 2.

A In **Figure 2**, the 555 oscillates with a period of 18 seconds. That is longer than you specified but the period can be shortened by reducing R3, and the rise and fall time can be shortened by reducing C2. R6 also affects the waveform; you may want to tweak it to compensate for variation in Q1 current gain. **Figure 3** is a plot of the simulated response showing the rise, fall, on, and off times. The white LEDs drop about 3.5 volts, so I was only able to put two in series and have enough voltage left for a current regulating resistor.



■ FIGURE 3.

PCMCIA MEMORY CARD

Q We have several CNC machine tools that use a PCMCIA memory card. What I would like to try to do is make an adapter that would fit in the PCMCIA card slot that would allow me to use a USB thumb drive or memory stick. I tried a USB cardbus adapter, but the machine tool control would not recognize the USB thumb drive. It may not be possible to have a simple way to read off of the USB thumb drive or download the programs from the machine control to the USB device. I would appreciate any help with this project.

— Brent Lamb

A I did a search for "PCMCIA to USB adapter" and discovered there are any number of them on the market, but all are specific to a host (e.g., Lenovo, Sony, Fujitsu, LG, Samsung, etc.). These are all the same physically but are not interchangeable, so I think the chances of finding one that will work with your machine are slim unless it is specified for that machine. Check with your machine maker.

Readers may have a solution to your problem; if so, I will forward it to you.

MULTI-STATION INTERCOM

Q I would like to put together an intercom system for my house. I want to be able to connect multiple stations, perhaps up to 10 or 12. Other than that, I think my requirements are pretty simple. I'd like to use twisted pair wiring, not shielded wire (for example, existing two pair telephone or four pair CAT 5). I would like to use a central power supply rather than individual batteries or power supplies. I don't need hands-free operation, so a simple push-to-talk function would be fine. I'm not concerned about privacy, so when one station is talking, all stations would hear the conversation.

I've seen some two-station circuits using LM386 but I can find nothing about creating a multi-station system. I would appreciate your suggestions.

— Terry Palmer

MAILBAG

Dear Russell: Re: Water softener question, January '12, page 22. I bought a water conditioner that is similar to the one you commented on in the Jan '12 issue, but is probably a different brand. Its name is CLEARWAVE that has been on the market for some 10 years and is sold by a reputable company — **smarthomes.com** — that I have dealt with for several years. Being a registered professional EE, I thought like you that it couldn't work.

However, in talking with Smarthomes, they have sold them for a few years and not had a problem with them. Then, I followed up on a study that the University of Michigan did which confirmed that it did indeed control the scale. I am on well water that used to deposit huge amounts of calcium carbonate on all my plumbing. I installed the Clearwave device on the copper tubing water pipe at the point of entry last April and a month or two later, the scale stopped forming completely. As the manual mentions, it does leave a light white power that is easily removed. I use only a wet paper towel.

Smarthomes provides a three month return policy on it and the manufacturer has a six month return policy. This is an extract from the manual which I did not follow up on:

Department of Energy Research on this technology. FEMP—FTA—Non-Chemical Technologies for Scale and Hardness Control Department of Energy (DOE/ EE- 0162) Federal Technology Non-Chemical Technologies for Alert Scale and Hardness Control Technology for improving energy efficiency through the removal of scale formation.

I am retired in Colorado and have no relationship with Smarthomes or the manufacturer.

— Jim

Response: Thanks for writing, Jim. I stand corrected. I don't know how it works, but several readers wrote to say they have had experience with this type of device, and it works. As you noted — and as others have told me — this is a water conditioner not a water softener; it does not remove iron.

Dear Russell: Re: US to European power, February '12. You answered a question about using American 115V equipment in Europe in the February issue. The solution offered was an inverter. This is a bit of overkill. Most higher power devices such as tools and heaters do not mind running on 50 Hz. A simple transformer will work fine. Power tools use "universal" brushed motors that will actually run on DC. Speed controllers may need AC though. In fact, most professional power tools in the UK are 110V for safety reasons. Portable transformers with a 110V secondary (center-tapped to earth so you get 55V maximum from line to earth) are common and affordable. The exceptions are anything that uses speed sensitive motors for timers, etc., and some marginally designed 60 Hz transformers can overheat on 50 Hz if fully loaded. Avoid low cost "electronic" converters. These are just fixed phase angle controllers — like light dimmers — that reduce the average voltage by turning the circuit off half the time. These are only useable on pure resistive loads like heaters. Even then, they put out peak voltages that may exceed the insulation ratings of the equipment.

— Robert Atkinson G8RPI

Response: The reader did not want a transformer solution; but you raise some important considerations in power conversion. Thanks for writing.

Dear Russell: Re: LED circuit wanted, January '12. You have an error in your answer to Scott Gates. White LEDs are most commonly made from a blue LED shining into a yellow phosphor. RGB LEDs shine white by combining all three colors, and a white LED could be made of all three combined, but that is not the norm.

You can easily prove this to yourself by shining a bright blue light into a white LED. The LED will glow white due to the yellow phosphor.

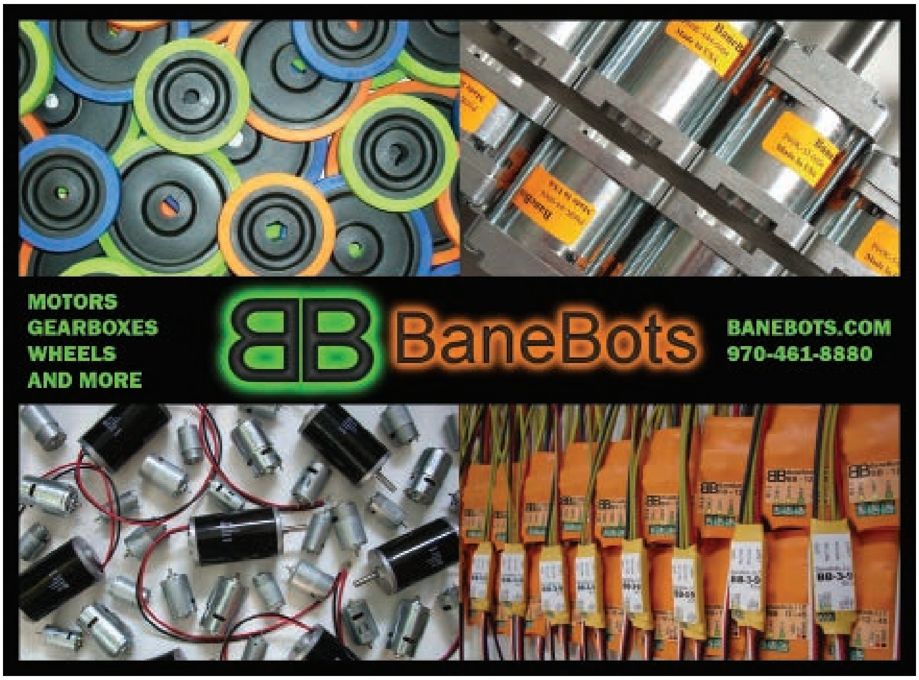
This article explains some of the more technical details, though the image is mistaken. The phosphor is usually contained inside the plastic and is visible from the top (**www.mt-berlin.com/frames_cryst/descriptions/led_phosphors.htm**). I'm not sure about the accuracy of the article, but it at least gives a good idea of how/why it works. White LEDs thus operate at the same nominal voltage as blue LEDs.

— Sam

Response: Thanks for writing, Sam.

A All you need to do is purchase as many as you need of RadioShack part number 55036742 wireless FM intercom pairs. You have to buy them online, but you can have them shipped to the nearest store to save shipping costs. Put them all on the same channel and you have the system you want.

These units use the house AC wiring for signal distribution, so you don't need to do any additional wiring. The units have two channels, so if the neighbor has the same intercom, you can put yours on a different channel (or talk to them if you want). Alternately, you can separate the house and garage. I know I would be annoyed if I were working in the garage and had to listen to the kid's conversations! **NV**



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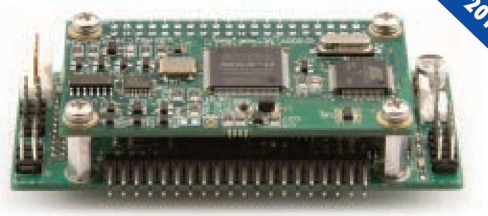

BUD is a compact Atmel ATmega640 microcontroller board with a big extra: when a BOB-4 module is installed, BUD easily generates complex text and graphics on TV monitors.

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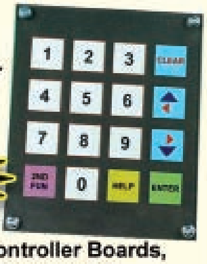

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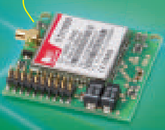

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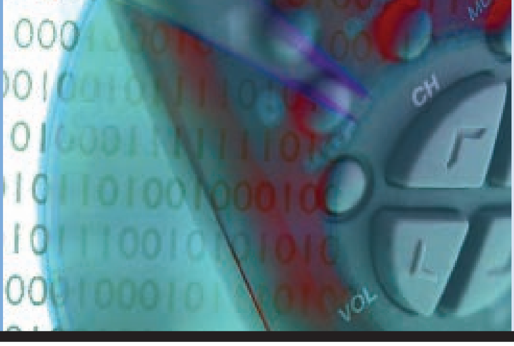

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New surface and through hole mount battery holders from Linx Technologies provide solid electrical contact for CR1216, CR1225, CR2016, CR2025, and CR2032 lithium coin and button cells. The compact design of the holders is perfect for space-constrained applications such as computers, remote controls, and other handheld electronics. The battery holder's low price makes them a good choice for high-volume projects. Their nickel-plated phosphor bronze construction provides good conductivity and strength. Two metal arms secure the battery to the contact patch.

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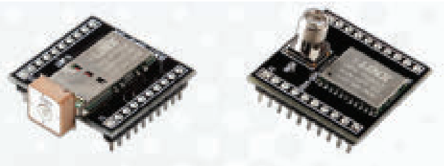
GPS daughterboards with attached modules — also from Linx Technologies — make it simple to add GPS functionality to solderless breadboards. Simply insert the daughterboard pins through breadboard holes for easy hand assembly. Daughterboards are available for the SG Series and SR Series GPS modules.



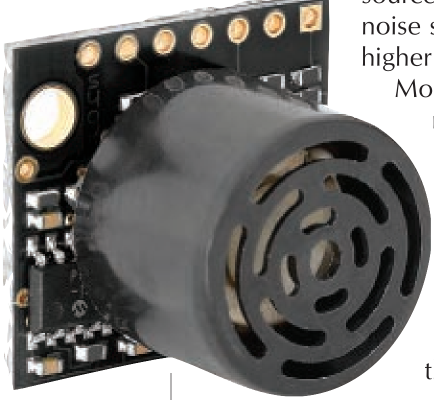
For more information, contact:
Linx Technologies
Tel: **800-736-6677**
Web: **www.linxtechnologies.com**

Correction!

Last month on mikroElektronika's new product information, the company name and website were listed incorrectly. Their correct website is **www.mikroe.com**. Our apologies for any confusion.

ULTRASONIC DISTANCE SENSING RANGEFINDER

MaxBotix, Inc., is now offering the next generation of the MaxSonar ultrasonic rangefinder. The HRLV-MaxSonar-EZ sensor line features 1 mm resolution, target size compensation for improved accuracy, simultaneous automatic multi-sensor operation, superior rejection of outside noise sources, temperature compensation, five meter range, and adds TTL serial output to the RS-232, pulse width and analog voltage outputs that are already standard on other MaxSonar products.



The 1 mm resolution is stable enough that when measuring typical objects at a distance of one meter, the readings do not change by more than 1 mm. The best stability is available with the TTL and RS-232 serial outputs with an error of ±0.1%. The pulse width has a stability of ±0.2%, while the rail-to-rail analog voltage output has a resolution of 5 mm.

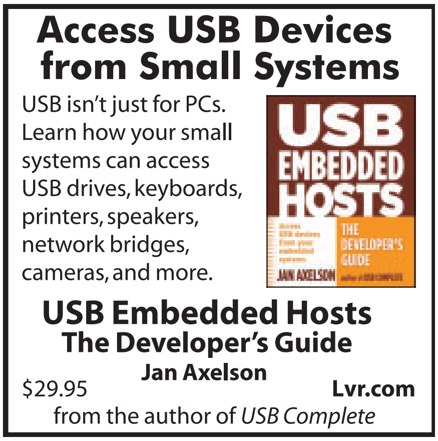
Most low-cost ultrasonic rangefinders will report the range to smaller size targets as farther than the actual distance. In addition, they will also report the range to larger size targets as closer than the actual distance. The HRLV-MaxSonar-EZ sensor line correctly compensates for target size differences. This means that if an object is large enough to be detected, the sensor will report the same distance regardless of target size. Other ultrasonic rangefinders will fail when used with other ultrasonic sensors nearby. By comparison, the HRLV-MaxSonar-EZ sensors can be used with other sensors in close proximity. Other nearby ultrasonic sensors will have little to no effect on the reported range of these sensors. The noise filtering of the HRLV-MaxSonar-EZ is now better than the previous MaxSonar products, and will work in the presence of many more noise sources and outside noise sources with higher amplitudes.

Most range readings are accurately reported, but if the range readings are affected the effect is typically less than 2 cm.

The HRLV-MaxSonar-EZ sensor allows for accurate temperature compensation. The speed of sound changes about 0.6% per degree Centigrade. To compensate for this effect, the sensor must monitor the changes to air temperature while ignoring self-heating. Self-heating is an issue with internal temperature sensors, where the temperature increase is typically two to five degrees Centigrade. If ignored, this will cause a drift of the reported range of up to 3%.

The HRLV-MaxSonar-EZ comes

Continued on page 76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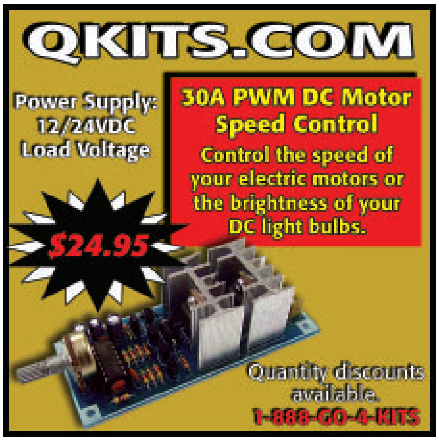
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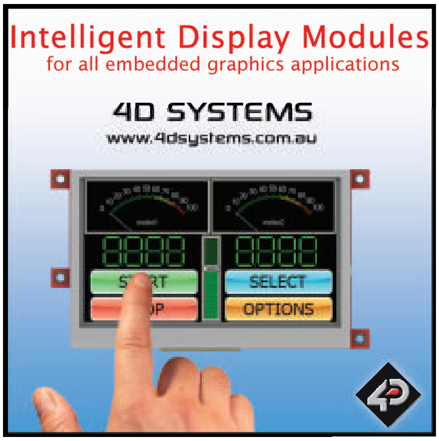
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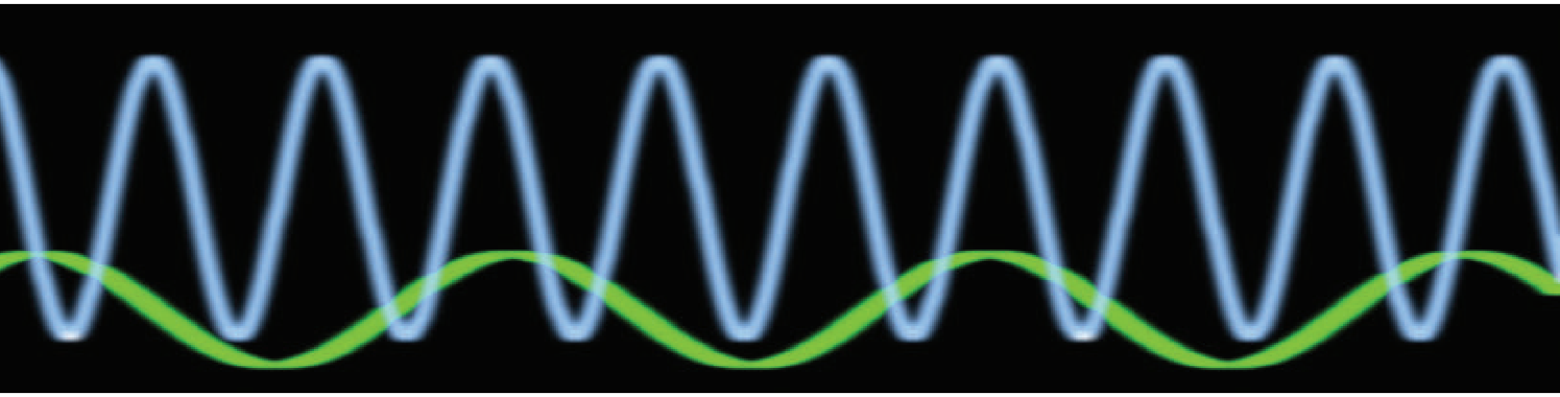
DDS and the Electronic Music Box

Make Music With Digitally Generated Analog Signals



By Craig A. Lindley

www.nutsvolts.com/index.php?/magazine/article/april2012_Lindley
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Analog signal generation is still a mainstay technology of electronics, even in an increasingly digital world. Analog signals find use in communication and radio systems, electronic test equipment, and musical applications to name just a few areas. Analog signals that were once created using discrete electronic components are more often than not produced digitally these days. It is no wonder analog signal generation has gone digital. Problems with component matching, temperature sensitivity, and component value drift requiring periodic calibration of the analog circuitry are gone. Of course, digital signal generation has its own set of issues including quantization and quantization noise, but techniques for dealing with these issues are well understood.

Direct digital synthesis or DDS is a method for digitally generating analog signals. With DDS, one creates a digital representation of the desired analog signal and then uses digital-to-analog (D-to-A) conversion to produce it. DDS systems allow quick switching between output frequencies, fine frequency resolution, and operation over a wide range of frequencies.

Although hardware DDS chips do exist, here we will be using software running on Arduino compatible microcontrollers to show DDS in operation. In this article, we will explore a musical application of DDS by building an electronic music box. First, let's go over some background on DDS to get us started.

A typical system for digital signal generation is shown in **Figure 1**. Here, some integral number of cycles of the desired signal are stored as samples in a wavetable. Every sample clock increments the address counter which provides the address of the next sample in the wavetable. That sample is output to a digital-to-analog converter (DAC) where it is converted to an analog voltage. A low pass filter (LPF) is generally employed to remove high frequency artifacts from the analog output that could result in aliasing. With this system, the frequency of the output waveform is controlled by the frequency of the sample clock; the faster the sampling clock, the higher the frequency. This, however, is inconvenient because the cutoff frequency of the LPF would need to change with the change in the sampling clock, complicating the design.

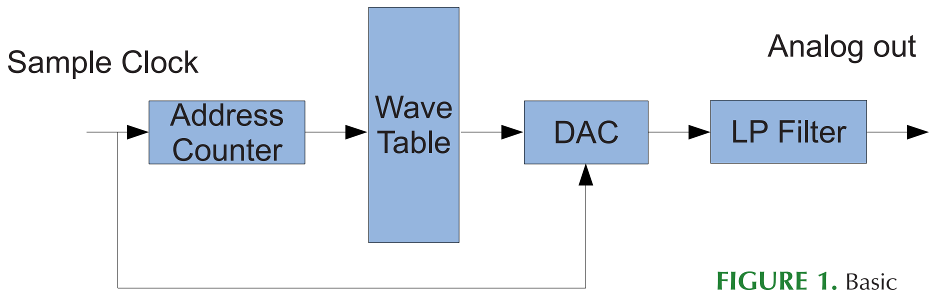

FIGURE 1. Basic wavetable system.

Figure 2 illustrates a basic DDS system which can produce different output frequencies without changing the frequency of the sample clock. It shares a lot of functionality with the previous technique, though it differs in how the addresses for the wavetable are generated. Every sample clock, the content of the frequency register is added to the contents of the phase accumulator which, in turn, is used to address the wavetable. The output frequency of this configuration is controlled by the DDS tuning equation:

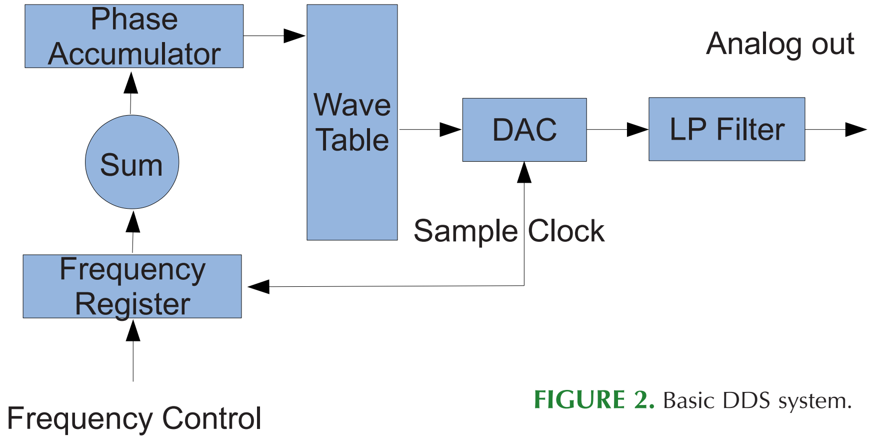

FIGURE 2. Basic DDS system.

$$F_{out} = M * F_{SampleRate} / 2^{n}$$

where **M** is the content of the frequency register and **n** is the number of bits which make up the phase accumulator. The bit width of the phase accumulator is important because it determines the frequency resolution of a DDS system and is described by the following equation:

$$F_{SampleRate} / 2^{n}$$

If the phase accumulator is 32 bits wide, the frequency resolution is one part in four billion, allowing for very precise frequency control. What the factor M represents can best be seen in **Figure 3** where the circumference of the circle represents one complete pass through the wavetable, typically containing one cycle of the desired output waveform. If M = 1, n = 32, and the sampling rate is 32,000 samples/second, the output frequency would be 7.45×10^{-6} Hz.

In a practical system, the size of the wavetable would be substantially smaller than the 32-bit width of the phase accumulator used to address it. In practice, a significant number of the least significant bits (LSB) of the phase accumulator would be truncated, resulting in a much smaller address space. Theory shows that this truncation does not affect frequency resolution but does adds a small amount of phase noise to the output.

If we have a 256 entry wavetable (requiring eight bits of address) containing one cycle of a sine waveform and we are sampling at 32,000 samples/second, we have a base or fundamental frequency of 32,000/256 or 125 Hz. If we wish to produce a 2,200 Hz sine wave as output with n = 32 bits, the value of M would be expressed as:

$$2^{32} * \text{output frequency} / \text{sample rate}$$

or the rounded value of M would be 295,279,002 which, in fact, is a fixed point representation of the fractional

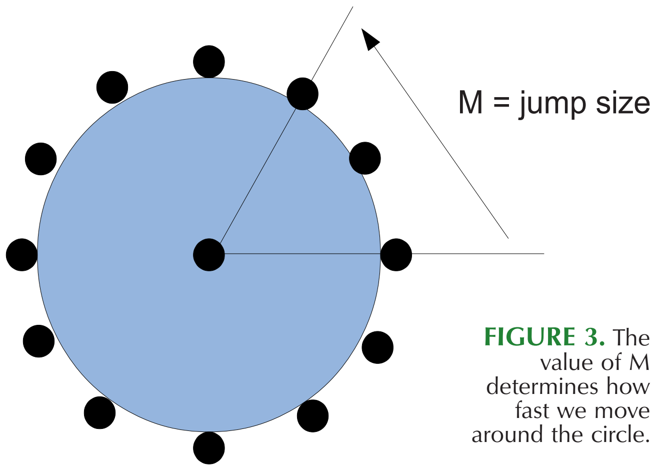

FIGURE 3. The value of M determines how fast we move around the circle.

value. To generate a 2,200 Hz sine wave in software, we would need an interrupt service routine (ISR) running at the 32,000 Hz sampling rate. Each time through the ISR, the value 295,279,002 would be added to the phase accumulator and then the phase value would be shifted to the right by 24 bits; the remaining eight most significant bits (MSB) would be used as the address into the wavetable for returning the sample to be sent to the DAC. With this number of bits and the sample rate specified, our DDS oscillator would have a frequency resolution of 0.00000745058 Hz.

Another thing to note about DDS is that phase is preserved when the frequency is changed. This is especially important in musical applications where a major discontinuity in phase may be audible when output frequency or pitch is altered.

Digital-to-Analog Conversion

Once digital samples are available, they must be converted into analog with some sort of D-to-A to analog conversion. Numerous techniques exist for doing this including:

1. Using a discrete D-to-A converter chip.
2. Building a D-to-A converter using an R2R resistor ladder network.
3. Using pulse width modulation (PWM) with filtering.

The technique employed depends upon the application. We will use technique number three for the electronic music box.

The Electronic Music Box

DDS can be used for the generation of periodic or non-periodic analog signals. So, let's have some fun and build an electronic music box. Our music box will emulate the sound of a mechanical music box which uses tuned metal tines plucked by pegs on a revolving drum.

This arrangement produces single notes and multi-note chords which have a high harmonic content after being plucked but become more sine wave like over time. Also, these notes decay in amplitude quickly giving music boxes their distinctive plucked sound.

We will build the electronic music box using just three components connected as shown in **Figure 5**:

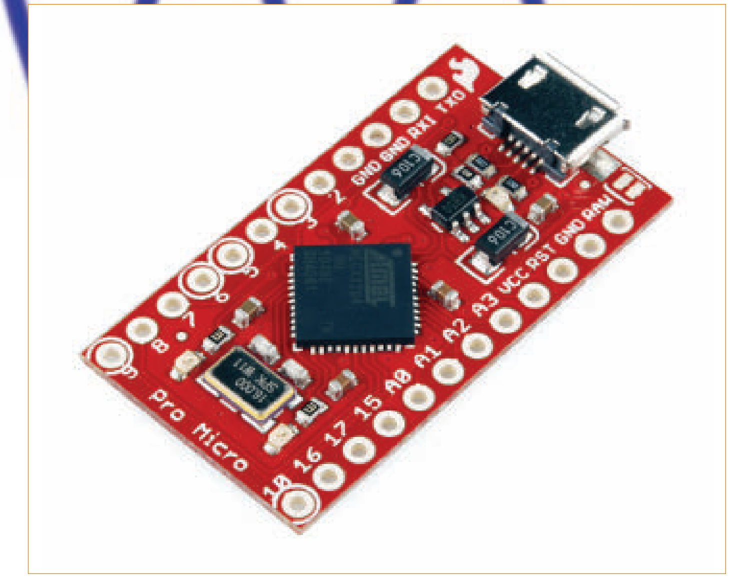

FIGURE 4. SparkFun's Pro Micro board based on the ATMega32U4 microcontroller. Dimensions are approximately 1.25" x .75" which makes for a small electronic music box.

RESOURCES

The following links may be of interest to those seeking more information on the topics described in this article:

The official source of Arduino information
http://arduino.cc

The free and open source Arduino development tools for Windows, OSX, and Linux (available for free)
http://arduino.cc/en/Main/Software

Information about the SparkFun Pro Micro
www.sparkfun.com/products/10998

All of the software described in this article is available on the *Nuts & Volts* website at the article link. The zip file called ddsmusicbox.zip contains the following:

1. The music box sketch for the Arduino Uno based on the ATMega328 processor (MusicBox.ino).
2. The music box sketch for SparkFun's Pro Micro Arduino compatible board based on the ATMega32U4 processor (MusicBoxProMicro.ino).
3. A Java jar file called musicboxsupport.jar which contains the software tools (both in executable and source code forms) necessary to support the music box's operation, and to add to or change the tunes in the music box.
4. An mp3 file of the music box playing Fur Elise.

A technical tutorial on digital signal synthesis is available from Analog Devices at **www.analog.com/static/imported-files/tutorials/MT-085.pdf**.

The original idea for a DDS music box came from the article entitled *Wavetable Melody Generator* described at **http://elm-chan.org/works/mxb/report.html**.

1. An Arduino compatible microcontroller (**Figure 4**).
2. A 100 ohm 1/4 watt 5% resistor.
3. A small 100 ohm speaker.

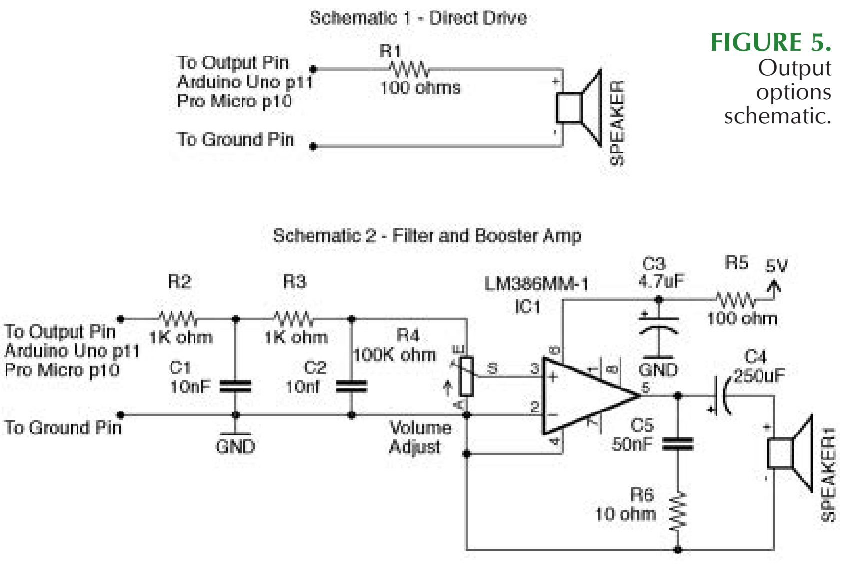

FIGURE 5. Output options schematic.

This configuration works without the use of filtering because the frequency of the PWM signal and the chosen sample rate are so far above the frequency response of the speaker they cannot be heard. The volume the direct drive approach produces may be insufficient for some applications. If so, an amplifier can be added as also shown on the schematic.

Our music box can play three songs: Fur Elise; Twinkle, Twinkle, Little Star; and Greensleeves, and is capable of playing three notes simultaneously. (See **Resources** for the Arduino sketches.) The sketch/code is too long to print, so we will just discuss how DDS makes the electronic music box possible.

Truth be told, the idea of an electronic music box wasn't mine. I came upon the idea at **http://elm-chan.org/works/mxb/report.html** while doing DDS research on the Internet. While I did adopt techniques presented there, the implementation I provide with this article is entirely my own.

For something so simple in concept, the electronic music box code is surprisingly complex and took time to get working. Implementing three simultaneous voices (called sound generators in the code) each with their own attack, sustain, and decay characteristics stretches the eight-bit microcontroller to its real time limit.

More voices would be possible if the code were written in assembler but I didn't want to go there just for a demo program.

Hardware Setup

The music box code takes advantage of hardware

Microcontroller	Music Box Sketch	Timer 1	Timer 2	Timer 4
ATMega328 as used in the Arduino Uno	MusicBox.ino	Used to generate an interrupt at the 32,000 Hz sample rate	Fast eight-bit PWM running at 62,500 Hz	Not Available
ATMega32U4 as used in SparkFun's Pro Micro	MusicBoxPro Micro.ino	Used to generate an interrupt at the 32,000 Hz sample rate	Unused	Fast eight-bit PWM running at 187,500 Hz

Table 1. Electronic music box hardware usage.

Data Array	Data Type	Usage Description
Song1Data in PROGMEM	uint16_t	Song data for Fur Elise. All song data was processed from MIDI files by MidiParser.java. Each note consists of two data items: note start time and MIDI note number. A note start time of zero indicates the end of the song.
Song2Data in PROGMEM	uint16_t	Song data for Twinkle, Twinkle, Little Star.
Song3Data in PROGMEM	uint16_t	Song data for Greensleeves.
MidiPitchData in RAM	uint16_t	The M values corresponding to the frequencies of the MIDI note numbers 0..127 in fixed point 8.8 format. Data generated by ScaleGenerator.java.
EnvelopeData in PROGMEM	uint8_t	The 8.8 fixed point numbers representing an exponentially decaying value (**Figure 7**). This is used to add the decay dynamic to each music box note. Envelope data generated by EnvelopeGenerator.java. An envelope value of zero indicates the end of the decay envelope.
WaveTableData in PROGMEM	int8_t	Signed sample data for the attack (**Figure 6**) and sustain (**Figure 8**) portions of the music box note waveform. Attack data generated by AttackGenerator.java; sustain data by SustainGenerator.java.

Table 2. Music box data arrays.

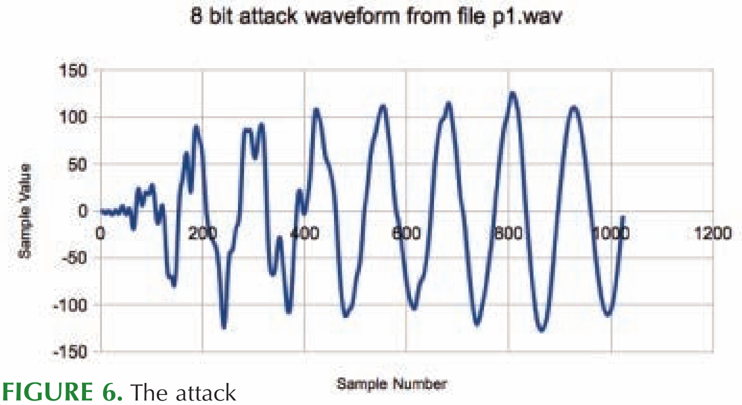

FIGURE 6. The attack waveform.

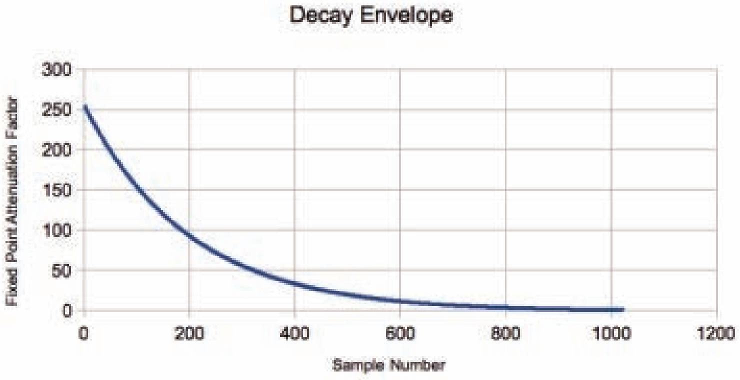

FIGURE 7. The decay envelope.

built into the ATMega chips. See **Table 1**.

The timers are configured for operation in the ***setup()*** portion of the Arduino sketches.

Music Box Data

The music box requires lots of data. Most of this data was generated by a series of Java tools I wrote specifically for this purpose (see **Resources**). **Table 2** describes the music box data. (NOTE: There is too much data to fit into the small amount of RAM available on these microcontrollers. For this reason, much of the data is stored in program memory which requires special handling to access. See the code for details.)

The music box uses other data, as well. Most importantly, the data that defines the sound generators. Three sound generators are required to play three simultaneous notes. A sound generator is defined by three variables:

- The ***m*** value which contains M for the sound generator that defines which frequency is being produced.
- The ***phaseAccumulator*** value to which ***m*** is added each sample time and which — after shifting — provides the address to look up in the wavetable.
- The ***envelopeIndex*** value which controls the amplitude decay of the note a sound generator is playing.

A sound generator is selected for each note in a song. If the selected sound generator is busy playing a previous note, note playback is terminated and the new note sounds. Premature note termination can sometimes be heard, especially when low frequency notes are being played. Increasing the number of sound generators helps with this problem but you soon run up against the real time processing limit of the processor.

Timing

Accurate timing is extremely important for music reproduction because the human ear is very sensitive to tempo and timing issues. This is true whether we are talking about a musician playing a real musical instrument or our music box playing a song. To this end, the music box code establishes a time base based on the execution of the 32,000 Hz sample rate interrupt triggered by a hardware timer. Each time through this ISR, a volatile 32-bit variable ***sampleCount*** is incremented. From ***sampleCount***, the program derives ***tickCount*** which controls the tempo of the song played. More on this in a moment.

Music Box Operation

With the majority of the data the music box uses described above, we can now talk about how the program actually works. We will do this by describing the foreground and background processes separately.

The Foreground Process

The foreground process is the code that runs in the sketch's ***loop()*** function which repeats forever. This code is concerned with playing songs on a note-by-note basis and is therefore interested in which song is currently being played, when the next note needs to be scheduled, and the frequency of the next note.

Basically, the next note is fetched from a song's data array and its start time examined. If zero, the end of the current song has been reached and setup for the next song occurs. If non-zero, the start time is compared to ***tickCount.*** If it is not yet time for the note to sound, the code loops waiting for the proper start time.

Once the note's start time is reached, a sound generator is assigned and initialized for this note's reproduction. Initialization consists of writing the M value for the MIDI note into the sound generator's ***m*** variable and clearing both its ***phaseAccumulator*** and ***envelopeIndex*** values. After the sound generator assignment is made the loop repeats waiting for the next note.

The Background Process

The background process is the real time code which runs in the ISR at the 32,000 Hz sample rate. In this code, every cycle is important, and keeping time-consuming operations like multiplications and divisions to a minimum is absolutely necessary. Fixed point calculations are used in the ISR because floating point operations on the fractional values would be to costly.

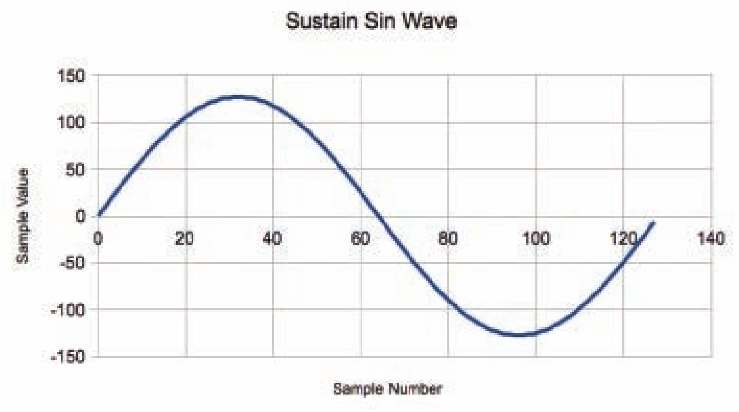

FIGURE 8. The sustain waveform.

The first order of business in the ISR is the processing of the three sound generators. For each sound generator, the ***phaseAccumulator*** value is fetched and shifted to produce the address of the next sample in the wavetable.

Next, the ***m*** value for this sound generator is added to the ***phaseAccumulator*** and a test is made to determine if all of the values in the wavetable have already been output. If so, the ***phaseAccumulator*** value is reset so that the sustain portion of the wavetable is set to repeat the next sample time, and a variable called ***decaying*** is set which controls note amplitude decay.

The sample from the wavetable and the value of the decay envelope are then fetched from program memory. These values are multiplied together and the result added to that of the other sound generators. Finally if the note is

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AUTHOR BIO

Craig has been interested in the production of lights/sounds/music with computers for a long time. He is the author of the book *Digital Audio with Java* published by Prentice-Hall. He lives in the mountains of Colorado and can be contacted at calhjh@gmail.com. When not messing around with electronics and/or computer projects, wood working, or beer brewing, he does a solo musical act around Colorado Springs.

decaying, the index into the envelope data is incremented for next time.

After all the sound generators have been processed, the sum of all the sample values is scaled into the appropriate range and set into the PWM timer's count register.

Some notes about sound generators are in order here.

Sound generators only run during the ISR. As a sound generator steps through the wavetable, it produces a waveform that is initially high in harmonics (see **Figure 6**) but gets more sine wave like at the end of the attack period.

The sustain portion of the wavetable is repeated over and over unless a new note is assigned to the sound generator. Programmatic repetition of the sustain portion of the wavetable data was implemented to reduce the overall size of the wavetable.

The multiplication of the wavetable sample with the value of the envelope controls note decay. Note decay begins after the first full pass through the wavetable is completed and the ***decaying*** variable is set. Once the envelope data reaches zero, the sound generator no longer contributes to the final PWM sample.

Conclusion

DDS is a powerful technique for analog signal generation that can be used in a variety of applications, and which can be implemented in hardware or software. In this article, we described the basic theory behind DDS and then went on to implement an electronic music box as an example application. In a future follow-up article, we will use DDS to build a multi-waveform audio frequency function generator.

Until then, enjoy your new electronic music box. **NV**

Analog signal graphics courtesy of ***http://creativity103.com/***.

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THEY SAID IT COULDN'T BE DONE SO WE DID IT

Return To Transistor Land

By Keith Bayern

The July '09 issue of Nuts & Volts featured an article on building a clock using no microcontrollers or integrated circuits. The project used seven-segment LED displays to indicate the time, and operated from 12 VAC. Keith has since modified the design to use high voltage Nixie tubes. This article shows the process by which Keith was able to design a no-IC, high-voltage power supply to power the tubes from the available 12V.

After designing the Transistor clock which was featured in the July '09 issue of *Nuts & Volts*, I wanted to change out the 1960's LED displays for 1950's Nixie tubes while still retaining the "no integrated circuits" theme. The logical changes were minimal; the hard part was generating 180 volts from the low voltage available on the board.

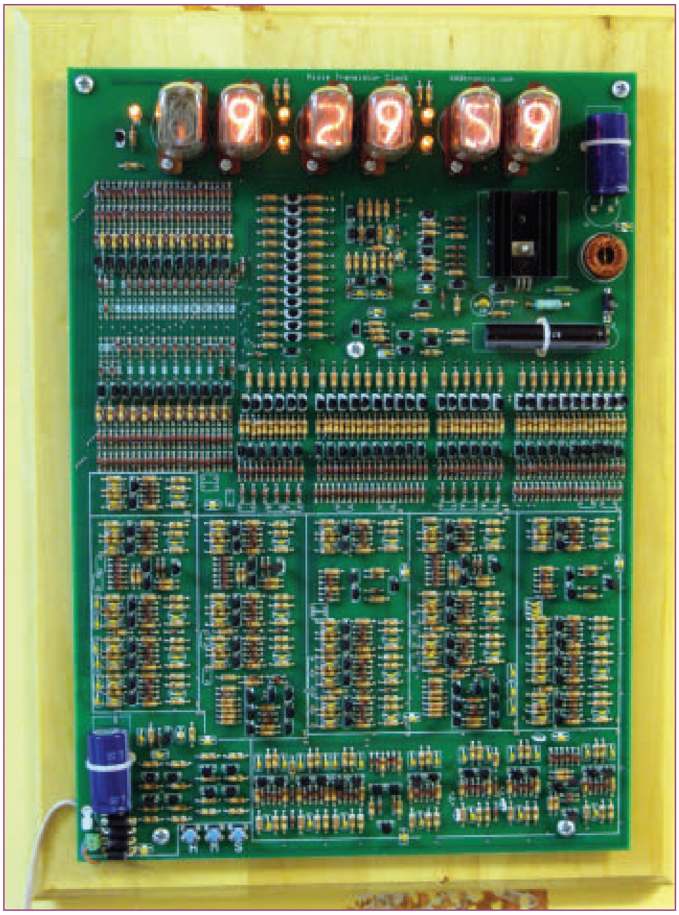


Figure 1. The updated Nixie-Transistor Clock.

Design

After choosing the Russian IN-12A Nixie tube (hats off to the Russian vacuum tube industry of the past), I calculated that driving six Nixie displays and five ne-2 neon bulbs would require 180 volts and 25 milliamps.

The basic circuit for the step-up switching supply is shown in **Figure 2**.

A Quick Pass Through the Block Diagram

When the switch closes, the inductor is placed across the 12 volt supply. Current starts at zero, but increases over time until two amps are passing through the inductor. This two amp current builds a magnetic field around the windings in the inductor. The two amp detector signals the S-R latch to open the switch. The magnetic field in the inductor collapse; the current in the inductor cannot instantaneously stop, so charge "piles up" on the right side of the inductor until the voltage reaches 180 volts. (Why 180? Read on ...) At this point, the diode becomes forward biased and turns on. The current can then flow into the capacitor, charging the capacitor and bumping the voltage up a bit.

This cycle repeats, bumping the capacitor voltage even higher until the 180 volt detector prevents the S-R latch from turning on the switch. The frequency of this cycle — switch on, switch off — is controlled by the oscillator. The length of the charge time is determined by how long it takes the current to reach two amps when charging the inductor. The length of the off time per cycle is controlled by the remaining time left within a cycle.

Cycle Details

Two equations are highlighted by this article:

- For a capacitor: $I = C\, dV/dT$, meaning that the current flowing in a capacitor is equal to the change of voltage times a constant. The constant is the capacitance. One amp is forced through a one farad capacitor which causes a change of one volt every second across that capacitor.
- For an inductor: $V = L\, dI/dT$, meaning that voltage across an inductor is equal to the change of current times a constant. The constant is the inductance. One volt impressed across a one henry inductor causes the current to change at a rate of one amp every second.

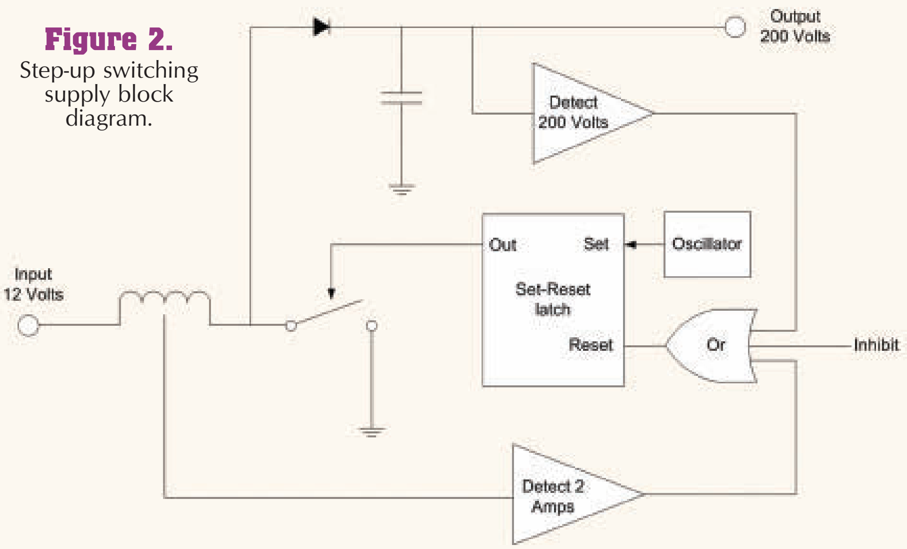


Figure 2. Step-up switching supply block diagram.

Returning to the switching power supply ... a 220 microHenry inductor is placed across the 12 volt supply, so the current is at a rate of 54.5 thousand amps per second. At that rate, it takes about 37 microSeconds to reach two amps.

During the discharge phase, the voltage across the inductor is 168 volts (180-12, ignoring the diode drop voltage). The rate of current change during discharge is 764000 amp/S, ramping from two amps to 0 in 2.6 microSeconds. The time to complete the cycle is about 40 microseconds, so as long as the oscillator runs slower than 25 kHz, there is time to complete a charge/discharge cycle.

Energy Accounting

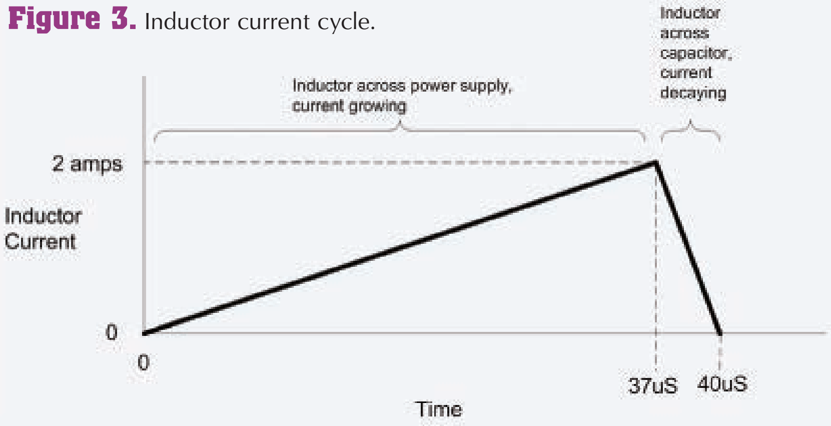
Each cycle transfers energy from the 12 volt supply to the 180 volt output capacitor which in this circuit is 120 microFarads. The energy stored in the inductor at the peak current of two amps is $E = 1/2\, LI^2$, so 440 μJ. When the inductor discharges into the 120 microFarad capacitor — since $E = 1/2\, cV^2$ — the voltage rises by 2.71 volts.

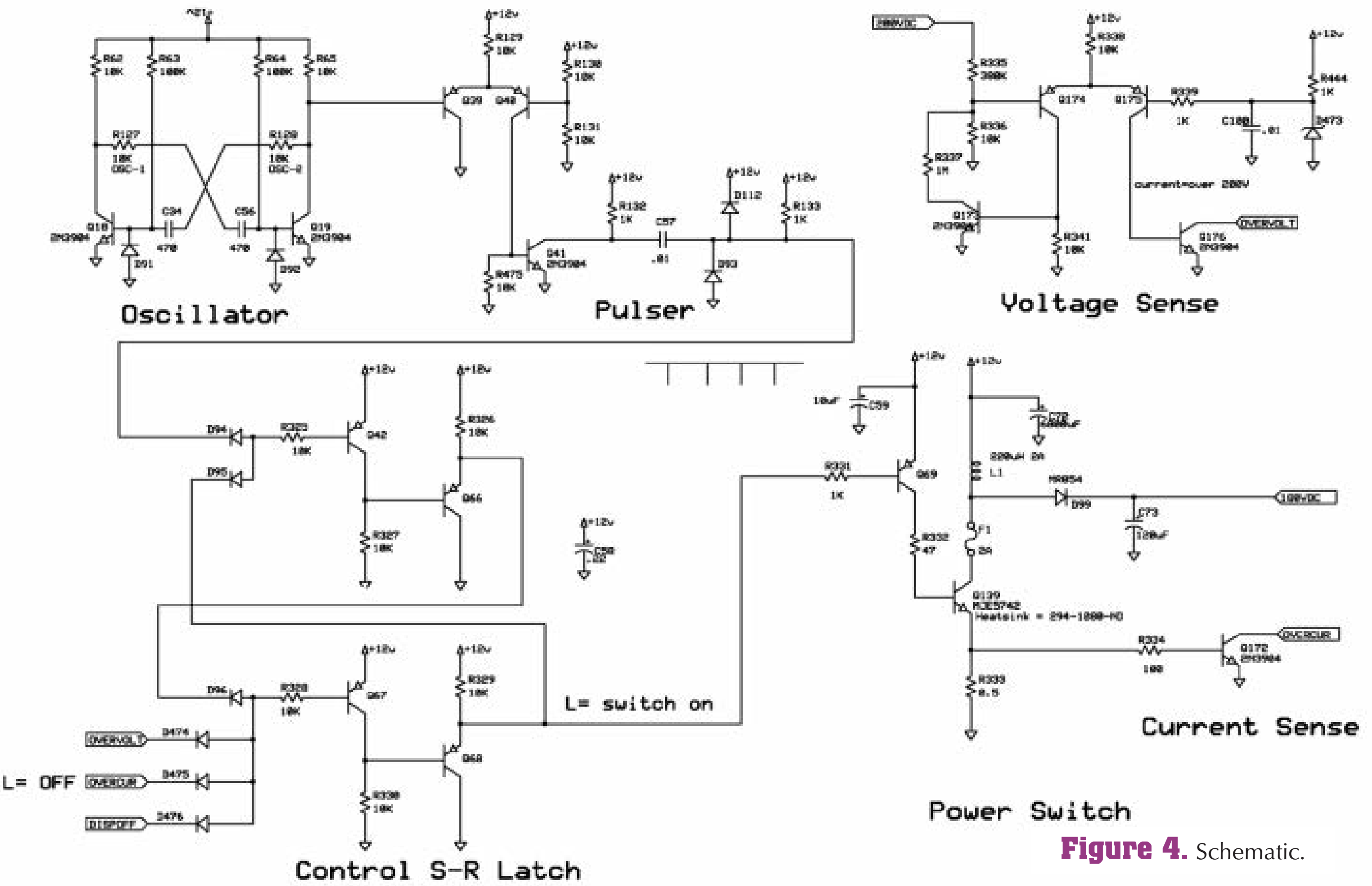
At power-up, the capacitor is at zero volts, so the 180 volt detector will not trigger; the cycle will repeat until the voltage steps up to and exceeds 180 volts. The Nixie displays will draw current out of the capacitor causing the voltage will drop, and the cycles will run again until the voltage rises above 180 again. The duty cycle is uncontrolled, so the skipped cycles are random, but that is not a concern.

Unfortunately in the real world, there are many imperfections that slightly affect this circuit — all negatively. The 12 volt supply is unregulated, so the energy drawn by the inductor (the two amp current ramps) causes the 12 volts to droop. At first, I used that 12 volts as the reference for the 180 volt detector. When I saw the 60 Hz ripple in the 180 volt output, I added a zener diode voltage reference which fixed that problem along with another odd problem mentioned below.

The inductor resistance is 0.12 ohms, so it dissipates about 0.24 watts and takes longer to reach two amps since that reduces the voltage across it. The transistor switch also has a voltage drop, further reducing the voltage across the inductor and dissipating more wasted energy. The inductor windings move as the current builds, and although the 22 kHz oscillator is too high to hear, the

Figure 3. Inductor current cycle.

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Q41 2N3904
R475 10K
D93
Pulser
200VDC
R335 300K
R336 10K
R337 1M
R338 10K
Q174
Q173
R339 1K
C108 .01
R444 1K
D473
current=over 200V
Q177 2N3904
R341 10K
Q176 2N3904
OVERVOLT
Voltage Sense
D94
D95
R325 10K
Q42
R326 10K
Q66
R327 10K
C58 .02
D96
R328 10K
Q67
R329 10K
Q68
R330 10K
L= switch on
OVERVOLT
OVERCUR
DISPOFF
D474
D475
D476
L= OFF
Control S-R Latch
10uF C59
C72 4000uF
220uH 2A L1
MR854 D99
100VDC
C73 120uF
R331 1K
Q69
R332 47
F1 2A
Q139 MJE5742
Heatsink = 294-1000-ND
R334 100
Q172 2N3904
OVERCUR
R333 0.5
Current Sense
Power Switch

Figure 4. Schematic.

random cycle skipping causes a whooshing sound to occur. A potted inductor would help.

Building the Circuit

The schematic implements the block diagram using transistors to build the oscillator, S-R logic, and the voltage and current detectors. I populated the oscillator first, got it running at about 22 kHz, then built the pulser. The pulser was needed since I wanted the S-R to not be receiving the go signal for more than a short pulse. To bring up the supply, I started with a much larger valued resistor in the current sense location below the switch transistor. When I saw the current detector working at 20 milliamps, I changed the sense resistor back to the 0.5 ohm value which results in about two amps detection. Initially, I loaded the voltage detection trip point to 20 volts, and when I saw that working, I changed the resistor value to allow for the 180 volts.

The upper trace is the collector of the switching transistor where it connects to the right side of the inductor at 50 volts per division. The lower trace is the inductor current at one amp per division.

At the start, you can see 12 volts on the inductor and zero current. Part way through the first

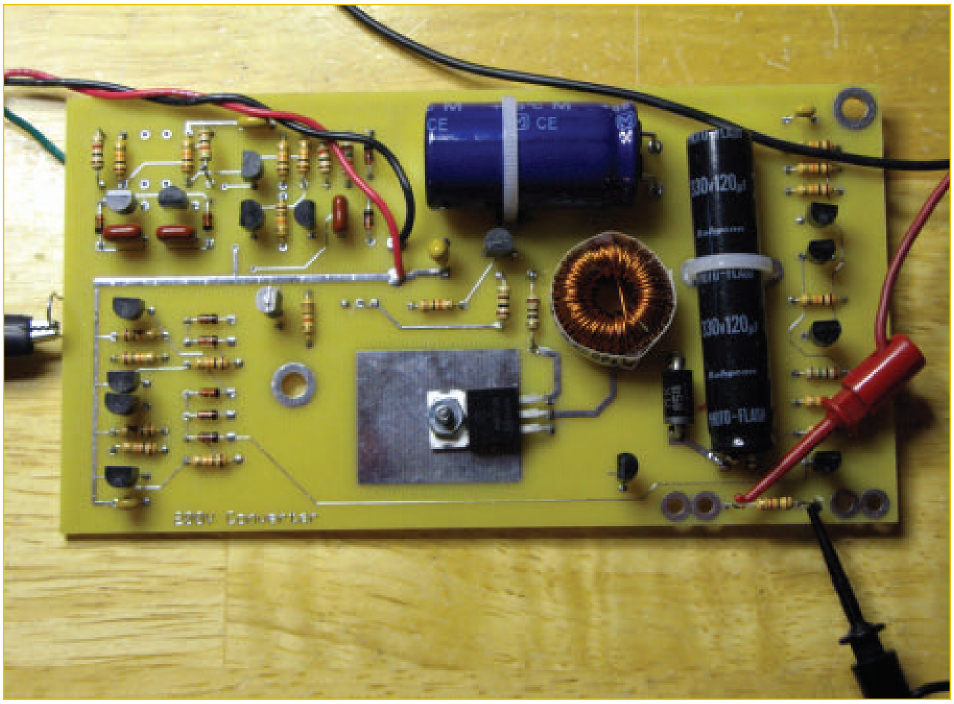
200V Converter

Figure 5. Test board.

division, the switch closes, the voltage drops to near zero, and current starts to ramp up. When the current nears two amps, the switch turns off, the voltage jumps to 180 volts, and the current quickly ramps down to zero. You can see some ringing that quickly dies down due to imperfect transistor and diode switching effects.

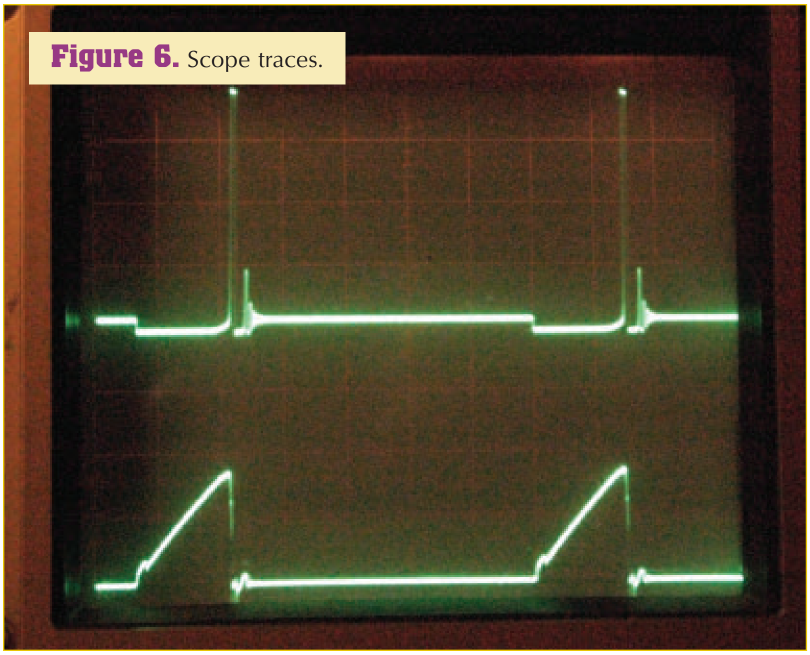
Figure 6. Scope traces.

Problems Encountered

This project presents many interesting issues. I was expecting 90% efficiencies and that ridiculous expectation caused me to miscalculate component values. There are odd multivariable trade-offs in a switching power supply. The cycle time versus energy per cycle versus inductor current is a tricky one. The faster you oscillate, the faster you need to charge up the inductor.

There are two ways to do that: higher input voltage and lower inductance. The energy transferred during each cycle is proportional to i^2, while the rate is linearly related to the inductance. Too short a cycle time and you can't charge the inductor; lower the inductor and you don't transfer enough energy to meet throughput needs.

You can't lower the cycle time below 20 kHz or you will drive humans crazy with the whine. The faster you oscillate, the more energy is lost in the transistor since it has losses each cycle as it transitions off and on. I spent much time recalculating and trying inductors from 20 uH to 500 uH.

Another problem was inadvertent control loop coupling. Before I added the zener diode for voltage regulation, when a load was placed on the 180 volts the demand on the 12 volts caused the 12 volts to drop.

This caused the voltage detector to erroneously turn off the switcher, causing the 12 volts to recover, which caused the switcher to turn on. This was happening at a rate of about three times per second. That caused a lot of head scratching until I figured out the problem.

Time is Up

This project was challenging, but resulted in a single board Nixie tube clock running on 12 volts AC. If you missed the '09 original clock build, the entire article is available on the *Nuts & Volts* website. **NV**

PCBs and parts for both the original transistor clock and the newly designed HV Nixie tube version are available in the NV webstore (store.nutsvolts.com). A complete parts list is also available. You can view the 2009 article which explains the theory and construction details at www.nutsvolts.com/index.php?/magazine/article/transistor_clock.

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Add USB Devices To Your Projects

When I begin a project, I like to look for the easy way. Instead of starting from scratch, I try to find building blocks to do some of the work for me. For anything that involves I/O, USB devices are a good bet. Data storage, user input, printing, audio, video, and network communications are just a few of the functions that off-the-shelf USB devices can perform.

By Jan Axelson

www.nutsvolts.com/index.php?/magazine/article/april2012_Axelson

Discuss this article in the *Nuts & Volts* forums at http://forum.nutsvolts.com.

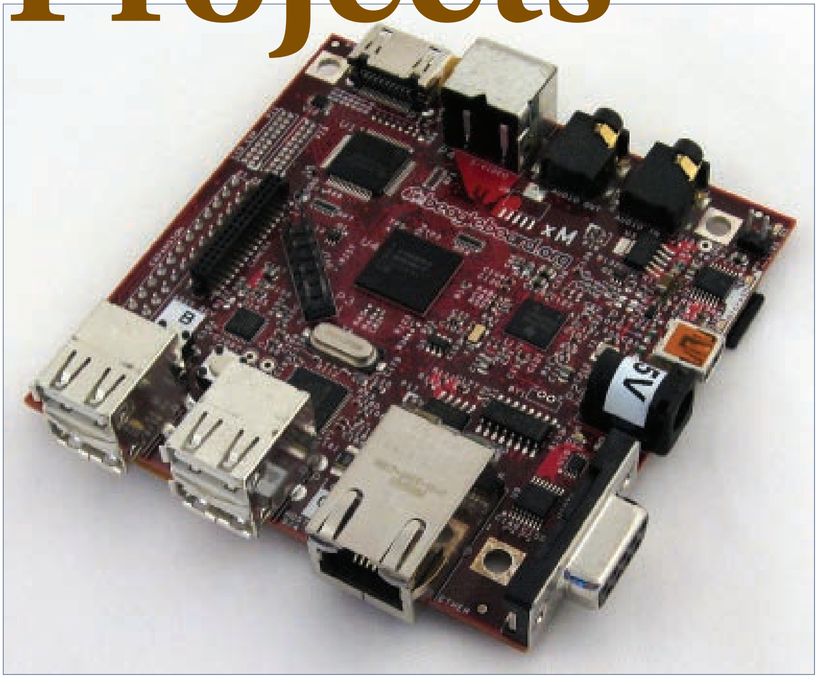


FIGURE 1. The BeagleBoard-xM has four USB host ports and one USB OTG port.

To access USB devices, a system must have USB host hardware, enough CPU capacity to manage the bus, and driver code that knows how to talk to the attached devices. PCs have all of these elements built in. However, for small systems such as handhelds or any device where system resources are limited, good support for communicating with USB devices can be hard to find.

The best small-system platform I've found for accessing USB devices is the BeagleBoard-xM open development board (**Figure 1**). The board has a powerful ARM processor with the resources to run the Linux OS, and Linux, in turn, has rich support for USB communications (and much more).

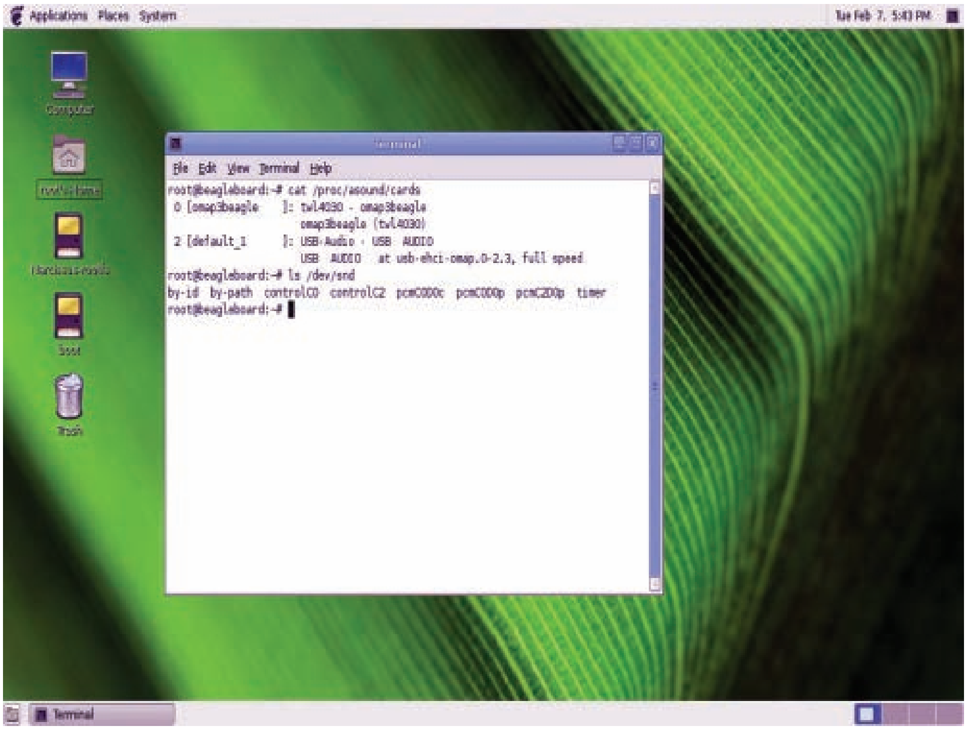
You say you've never used Linux before? Neither had I until I decided that the BeagleBoard-xM was as good an excuse as any to dive in. As with any new software, learning Linux takes some time and patience but the reward is the ability to take advantage of a powerful OS for projects big and small.

This article will show how to get started with the BeagleBoard-xM, including how to use a USB mic and speakers to record and play sounds of any kind — bird calls, music, or whatever suits your fancy.

Running Linux in a Small System

The BeagleBoard-xM originated at Texas Instruments — the source of the board's DM3730 ARM processor. The goal of the project was to create an open-source platform for experimenting and education.

To make the platform as flexible as possible, the board has an abundance of I/O interfaces. The USB support includes four USB host ports and a USB OTG port



```
root@beagleboard:~# cat /proc/asound/cards
 0 [omap3beagle    ]: twl4030 - omap3beagle
                      omap3beagle (twl4030)
 2 [default_1      ]: USB-Audio - USB  AUDIO
                      USB  AUDIO  at usb-ehci-omap.0-2.3, full speed
root@beagleboard:~# ls /dev/snd
by-id  by-path  controlC0  controlC2  pcmC0D0c  pcmC0D0p  pcmC2D0p  timer
root@beagleboard:~#
```

SCREENSHOT 1. The BeagleBoard-xM comes with a demo version of Linux on a micro-SD card.

that can function as either a host or a device port. All of the USB ports can communicate with low, full, and high speed USB devices. All of the ports support hubs which means you can add even more devices and extend the cabling. A built-in USB/Ethernet bridge supports network communications.

The board also has a DVI-D monitor connector, a JTAG port for debugging, S-video, stereo in and out, RS-232, LCD headers, and a camera header.

The BeagleBoard's website (**www.BeagleBoard.org**) has links to vendors that stock the board along with links to an active email discussion group, getting started Wikis, projects, and more.

Unlike many small systems that store their program code in onboard Flash memory, the BeagleBoard-xM runs its firmware from a microSD card in an onboard receptacle. The card that comes with the board contains a demo version of the Ångström distribution of Linux. Ångström is a stripped-down edition of Linux targeted to small systems. The board can also run other distributions of Linux — including Ubuntu — as well as other operating systems. You can swap an OS by swapping cards.

On powering up the board with the provided microSD card and an attached monitor and USB keyboard and mouse, you can use the BeagleBoard-xM much like a conventional Linux PC. You can load and run the programs you write and other Linux software as needed. Even if your final project doesn't need a display and keyboard, having these peripherals available can be a big help when developing and debugging code.

For command-line operations, you can run a terminal-emulator program by selecting Applications -> Accessories -> Terminal in the GUI (**Screenshot 1**). For tips on using terminal applications, see the **sidebar** "Five Timesavers."

Compiling and Running Programs

You can write, compile, and debug your programs right on the BeagleBoard-xM. A popular option is to use a separate development PC to write and cross-compile programs, and then transfer the executable files to the BeagleBoard-xM. The development PC can be just about any PC with a network connection.

Using Linux on the development PC makes sense when you're developing for Linux on the BeagleBoard-xM. If you don't have a Linux PC, you can install Linux as a

Five Timesavers for Typing in a Terminal

If you haven't used a terminal application in a while, you may be pleasantly surprised at the editing capabilities supported by the Linux GNOME terminal and similar applications. These tips can save you time and trouble when typing in a terminal application.

1. Use autocomplete. You only need to type enough letters for the terminal application to identify your intent. If you have a directory that contains the subdirectories Documents and Downloads to view the contents of Documents, type:

```
ls Doc
```

and press the Tab key. The terminal application completes the command for you:

```
ls Documents/
```

2. Use the history to repeat commands. Use the up-arrow key to scroll through the commands you've previously executed. Press Enter when you find the one you want.

3. Edit commands. Typo? Don't start over. Before pressing Enter, you can edit any command using the arrow keys to go to the location you want to edit.

4. Copy and paste. To copy text from anywhere on the terminal screen, select the text with a mouse, right-click, and select Copy. Right-click and select Paste to paste the text at the text cursor's current location. (Don't try to copy and paste with Ctrl+C and Ctrl+V as these key combinations have other uses in terminal applications.)

5. Remember that Linux is case-sensitive. Myfile.txt and myfile.txt are different files.

Sources

BeagleBoard website
www.BeagleBoard.org

Guide to cross-compiling for the BeagleBoard-xM
www.Lvr.com/eclipse1.htm

BeagleBoard example code
www.Lvr.com/beagleboard.htm

VMWare Player virtualization software
www.vmware.com/products/player

How to install Linux as a virtual machine
www.howtogeek.com/howto/11287/how-to-run-ubuntu-in-windows-7-with-vmware-player

Beginning the Linux Command Line
by Sander van Vugt (Apress)
www.apress.com/9781430218890

virtual machine in free disk space on a Windows PC. Linux then runs in an application window under Windows. I was skeptical of this approach until I tried it and found that it works very well.

I use VMWare's free VMPlayer virtualization software and the Ubuntu 11.10 distribution of Linux. Ubuntu is a popular Linux distribution for desktop PCs. VMWare recommends at least 1 GB of free disk space for each guest OS. See the **Sources** sidebar for links to tutorials on installing Linux, including installing Linux as a virtual machine under Windows.

For command-line operations in Ubuntu 11.10 with the Unity desktop, click the **Dash home** button in the upper left corner of the screen and search for the **terminal** application.

To enable transferring files between the development PC and the BeagleBoard-xM, connect both the development PC and the BeagleBoard-xM to an Ethernet hub or switch on your local network. If the local network connects to the Internet, you can download files from the Internet directly onto the BeagleBoard-xM.

Transfer Type	Control	Bulk	Interrupt	Isochronous
Required?	Yes	No	No	No
Low speed okay?	Yes	No	Yes	No
Error checking?	Yes	Yes	Yes	No
Guaranteed delivery rate?	No	No	No	Yes
Guaranteed max. latency?	No	No	Yes	Yes
Typical use	Enumeration	Printer	Keyboard	Audio

FIGURE 2. USB's four transfer types are each suited for different uses.

Installing the Tools

On the development PC, you'll need a toolchain for cross-compiling programs for the BeagleBoard-xM. I use the free gcc toolchain for C programming. Also useful is the free Eclipse IDE which provides an environment for writing, compiling, and even remote debugging of programs.

Installing a toolchain and configuring Eclipse for cross-compiling involves many steps. To help you along the way, I've posted an online guide that takes you from downloading a toolchain and Eclipse, to compiling and running your first program (see **Sources**). From there, you can begin developing and running your own programs.

Documentation for many Linux commands and applications is in **man** pages. To view the man page for the **ls** command in a terminal application on a desktop Linux system, enter **man ls**. To save space, the demo Ångström distribution doesn't include man pages. A Web search will also bring up most man pages.

The Ångström distribution includes the opkg utility for installing software. For example, to install the package alsa-utils in a terminal application on a system with an Internet connection, enter:

```
opkg install alsa-utils
```

The utility locates the appropriate package for the target system and installs the software, updates an existing installation, or notifies you that the installed package is up to date. There's no need to search the Web for the software or figure out which version is the right one for your hardware and OS. The utility does it all for you. In Ubuntu, the apt-get utility performs a similar function:

```
sudo apt-get install alsa-utils
```

Exploring USB Audio

USB supports four transfer types, each optimized for specific uses (**Figure 2**). Isochronous transfers are intended for uses such as streaming audio and video where moving the data at a constant rate is more important than correcting occasional data errors. Isochronous transfers are the most challenging transfer type for small systems because the USB host must send or receive data at a constant rate.

Linux supports isochronous transfers and also has drivers and applications for recording and playing audio (and video too!). The Linux Advanced Linux Sound Architecture (ALSA) component provides sound drivers and other support for audio functions. The ALSA applications "aplay" and "arecord" can play and record sounds. Other audio applications such as mplayer and lame add capabilities and support for more file formats.

In Linux, one or more "sound cards" provide audio functions. On the BeagleBoard-xM, the sound card isn't a separate card but instead resides on the same board as the processor.

To view the registered sound cards on a system in a terminal application, enter:

```
cat /proc/asound/cards
```

Here are entries for the BeagleBoard's built-in sound card and USB speakers:

```
0 [omap3beagle    ]: twl4030 - omap3beagle
                     omap3beagle (twl4030)
1 [default        ]: USB-Audio - USB  AUDIO
                     USB  AUDIO   at usb-ehci-
                     omap.0-2.2, full speed
```

Each entry consists of a card number followed by the card's name and additional information. In the example above, card 0 is the BeagleBoard-xM's onboard audio subsystem, and card 1 is attached USB speakers.

An application may specify a device node for playing or recording sound. To view the device nodes in a terminal application, enter:

```
ls /dev/snd
```

Here is the command's output for a BeagleBoard-xM with attached USB speakers:

```
by-id  by-path  controlC0  controlC1
pcmC0D0c  pcmC0D0p  pcmC1D0p  timer
```

To identify which device nodes belong to a USB device, view the /dev/snd directory before and after you attach the device.

In the example above, the USB speakers have two device nodes:

- controlC1 is the control device for card 1.
- pcmC1D0p is the audio device for card 1, device 0. (A single card can have multiple devices.)

Playing Sounds

The aplay application can play sounds in AU, RAW, VOC, or WAV formats. If not installed, install aplay and related utilities with:

```
opkg install alsa-utils
```

This command plays the file bittern.wav on card 1's device 0:

```
aplay -D plughw:1,0 bittern.wav
```

- -D plughw:1,0 specifies the output device as card 1's device 0.
- plughw is a plug-in layer that converts a file's sample format, sample frequency, and number of channels as needed to a format supported by the sound card.

The amixer application can set the volume and other features of the sound card. If not installed, install amixer with:

```
opkg install alsa-utils-amixer
```

The -c switch selects a sound card. This command sets the volume of card 1 (-c 1) to 40%:

```
amixer -c 1 set PCM 40%
```

The mute and unmute switches turn the audio on and off:

```
amixer -c 1 set PCM mute
amixer -c 1 set PCM unmute
```

The mplayer application supports additional file formats including MP3. If not installed, install mplayer with:

```
opkg install mplayer
```

This command plays an MP3 file:

```
mplayer -ao alsa:device=hw=1.0 sora.mp3
```

- -ao alsa:device=hw=1.0 specifies the audio output device (-ao) as card 1's device 0.
- sora.mp3 is the file to play.

The -af option can set the volume:

```
mplayer -ao alsa:device=hw=1.0 -af volume=10
sora.mp3
```

- -af volume=10 sets a gain of 10 dB. A gain of -200 mutes the sound. A gain of volnorm gives maximum gain without distortion.

PARTS LIST

- BeagleBoard-xM open development board (**www.BeagleBoard.org**)
- 5V DC 2A power supply, PHIHONG USA PSC12R-050 (available from **www.DigiKey.com**) or similar
- Display monitor with DVI-D port
- USB keyboard
- USB mouse
- Linux Development PC (can be a virtual machine; see article) for cross-compiling programs
- Network connection to the development PC and the Internet

```
#include <stdlib.h>

int main()
{
        system ("mplayer -ao alsa:device=hw=1.0 sora.mp3");
        return 0;
}
```

FIGURE 3. Use the Linux system command to run applications such as mplayer from within an application.

Figure 3 is an application that uses the system command to play a file with mplayer. The system command launches the mplayer application. You can use the system command in a similar way to launch other applications from within an application.

Recording Sounds

For recording audio, connect a USB mic to the BeagleBoard-xM. The arecord application included in alsa-utils can record sounds in AU, RAW, VOC, or WAV format.

As before, use the commands **cat /proc/asound/cards** and **ls /dev/snd** to view information about the mic. Use the amixer application to set the volume for the mic:

```
amixer -c 2 set Mic 100%
```

- -c 2 selects card 2.
- Mic 100% sets the gain to 100%.

This command records audio input from a USB mic to the file blackbird.wav:

```
arecord -D plughw:2,0 -r 16000 -f S16_LE -c
2 -d 3 blackbird.wav
```

- -D plughw:2,0 specifies the input device as card 2's device 0. The card and device numbers for the mic are in the /dev/snd directory described above.
- -r 16000 specifies a sampling rate of 16,000 Hz. The default is 8000. A too-high sampling rate can result in underrun errors and dropouts.
- -f S16_LE specifies signed 16-bit, little endian format.
- -c 2 specifies using two input channels. The default is one channel.
- -d 3 specifies recording for three seconds. If you eliminate this option or set it to zero, recording

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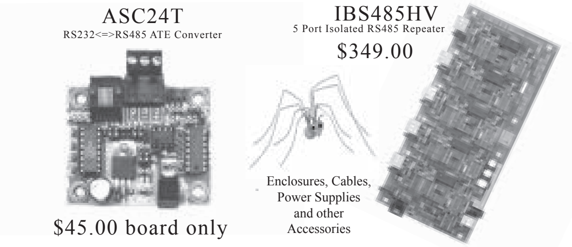
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continues until the process ends with Ctrl+C or another means.

To play the recording, use aplay as above with the filename blackbird.wav.

The MP3 format is popular in part because its compression dramatically reduces file size. The lame application can convert a raw file to a compressed file that MP3 players can play. Because MP3 technology is patented, you may need a license to include a compiled version of lame in a commercial product.

Install lame with:

```
opkg install lame
```

This example records a raw file and pipes it to lame which encodes the data and stores the result in a file:

```
arecord -D plughw:2,0 -r 16000 -f S16_LE -c
2 -t raw -d 3 | lame -s 16 -r -
blackbird.mp3
```

- arecord records the file using the same options as the previous example, plus the -t raw option to specify raw output format.
- | is the pipe operator that writes arecord's output to lame.

The lame application uses these options:

- -s 16 sets a sampling frequency of 16,000 Hz.
- -r specifies an output in raw pcm format.
- -(hyphen alone) specifies using standard input as the input source. In this example, the standard input to lame is the output from arecord.
- blackbird.mp3 stores the recorded mp3 file. Use mplayer as described above to play the file.

Exploring Further

Recording and playing audio is just one example of what you can do with the BeagleBoard-xM and USB. My website has code for accessing USB drives, printers, keyboards, virtual serial ports, and more. **NV**

Jan Axelson is the author of *USB Embedded Hosts*, *USB Complete*, and other books. This article is adapted from material in *USB Embedded Hosts*. Jan's website is **Lvr.com**.

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USING COLOR GRAPHICS AND WIDGETS WITH THE 32-BIT MICRO EXPERIMENTER

BY THOMAS KIBALO

Discuss this article in the Nuts & Volts forums at http://forum.nutsvolts.com.

Widgets are graphic objects that can imitate buttons, knobs, meters, slide controls, and check boxes on a graphics display. Widgets interact with users through touchscreens, keyboards, or simple pushbuttons, enhancing project displays by providing a highly functional virtual front panel for user interfaces. The really cool part is that widget code is already written and essentially just "plugs in" to your existing C code application using Microchip's free graphics library and following the straightforward API (Application Programming Interface).

Can you feel the power of widgets? We are here to show you how to harness that power.

In an earlier *Nuts & Volts* article (June '11), we introduced Microchip's graphics library. Back then, we focused mainly on its basic drawing capability for graphics primitives (i.e., lines, bitmaps, circles, different fonts, text, etc.), with a brief introduction to widgets. In this article, we will focus on a number of widget types: the button, slider, edit box, static text box, digital meter, and analog meter, working through five application demos. The demos are canned code and can be used immediately with your 32-bit projects. These demos use the Experimenter onboard pushbuttons and an optional PS/2 keyboard (see Oct '11 *Nuts & Volts* for details).

We will introduce a new color graphics module for use with the 32-bit Experimenter (see **Figure 1**). It is based on 4D Systems uLCD-144 (SGC) serial LCD display module. The uLCD-144 is 128 x RGB x 128 resolution, with 65K true to life colors; it has an LCD TFT screen with LED backlight coloring that measures 1.44" diagonal size. The module can be purchased at 4D systems (**www.4dsystems.com.au**). Quick hook-up directions are shown in **Figure 2**.

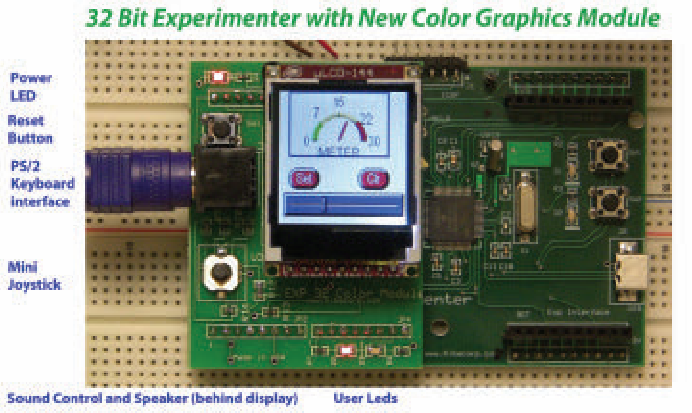
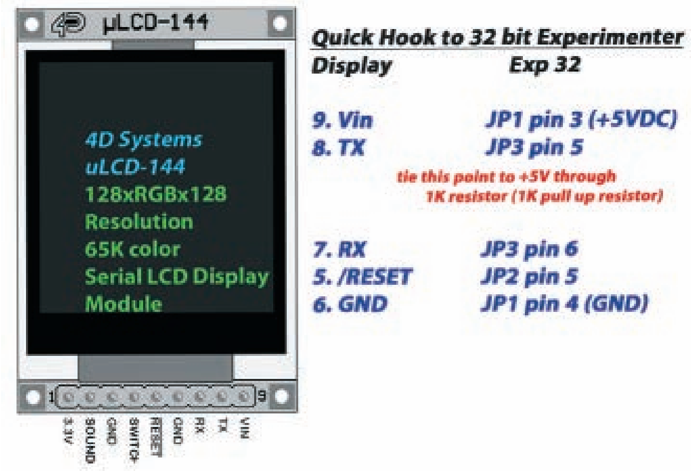

32 Bit Experimenter with New Color Graphics Module
Power LED
Reset Button
PS/2 Keyboard interface
Mini Joystick
Sound Control and Speaker (behind display)
User Leds
METER
Set
Clr

FIGURE 1. Experimenter and prototype color graphics module.



Quick Hook to 32 bit Experimenter

Display	Exp 32
9. Vin	JP1 pin 3 (+5VDC)
8. TX	JP3 pin 5
7. RX	JP3 pin 6
5. /RESET	JP2 pin 5
6. GND	JP1 pin 4 (GND)

tie this point to +5V through 1K resistor (1K pull up resistor)

FIGURE 2. The display to Experimenter hookup.

The module also has sound and input switch capability. A complete display carrier board for plug-in use with the Experimenter that provides full capability and a PS/2 interface will be made available through the *Nuts & Volts* Webstore. The demo code is provided (at the article link) to work with the new color graphics module and the existing Universal monochrome graphics module. The applications are:

- Multi-button widget display using just two physical pushbuttons for control for five different LEDs.
- Slider widget control of an LED.
- Dynamic widget analog meter and widget digital meter of potentiometer value input.
- Real Time Clock Calendar (RTCC) setting using widgets and keyboard.
- RGB LED light control using three slider widgets.

- Full color primitives demo with image, text, lines, and circles bars (color module only). See June '11 Experimenter article which provides descriptions.

As in all articles in this series, a general familiarity with C language is required.

Quick Overview of Microchip Graphics Library

Microchip created a graphics library to cover a broad range of microcontroller consumer product applications. These applications include home automation, industrial controls, and medical devices where graphical displays integrate control of motors, appliances, compressors, and temperature sensors, among others.

The library is a layered collection of configurable software modules where any layer can be incorporated and used through the API as needed for a particular application (see **Figure 3**). This allows users to access and configure as much of the library as required, without a lot of extensive rework. The library is already integrated and configured within the demos.

Our demo applications make extensive use of the Graphics Object Layer (GOL) to render widgets, and to interact and control the widgets. The GOL library message interface is used to allow the widgets to "see" and interact with system application hardware. More on this later.

The other layers are the Graphics Primitive Layer and Display Device Driver. These layers are transparent to us since we will not be interacting with them directly in the demos. The graphics layer implements primitive drawing functions; the device layer talks directly to the graphics module.

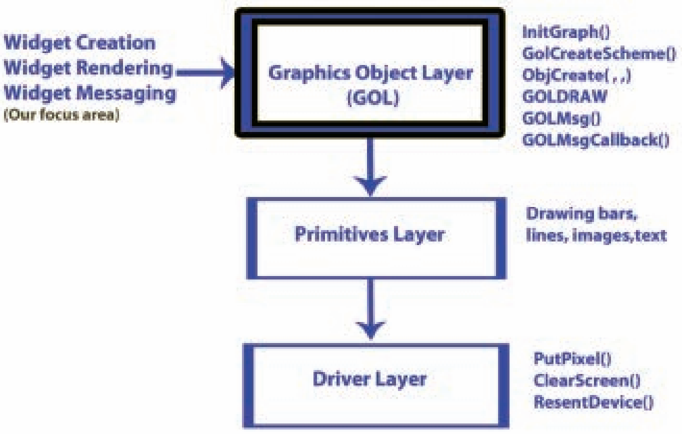
For assistance on any element within the graphics library portion, navigate to \Microchip\ Graphics\Help, and click the graphics library help icon. The graphics help library information is organized as a tree. Clicking on any element in the tree will help you navigate to the desired information.

Setting Up Your Project for Using Widgets

Widget setup is already done for you in the supplied demo set. However, in the event you decide to go off on your own, here are some helpful reminders. In the GraphicsConfig.h file within the library, uncomment all widget elements required for your design. The specific widgets we will use are shown uncommented below, as well as enabling of the library graphics layer:

```
#define USE_GOL              // Enable Graphics Object
                             // Layer.
#define USE_BUTTON           // Enable Button Object.
#define USE_EDITBOX          // Enable Edit Box
                             // Object.
```

FIGURE 3. Microchip graphics library.



```
#define USE_SLIDER           // Enable Slider or
                             // Scroll Bar Object.
#define USE_STATICTEXT              // Enable Static
                                    // Text Object.
#define USE_METER                   // Enable Meter
                                    // Object.
```

In addition, we need to select a system input which, in our case, is the keyboard (since the color module does not support a touchscreen); we also select focus control. We will use focus to select the active widget in our demos:

```
#define USE_FOCUS               // Enable focus control
#define USE_KEYBOARD            // Enable key board
                                // support.
```

For each widget, there is a specific driver and header file. For example, for BUTTON widget, you need to incorporate the BUTTON.C and BUTTON.H in your project. All these files are available in the Microchip/ Graphics folder within the library.

Now, let's move on to the Main function (LAB3.C in the demo projects).

Primarily, we need to create a unique handle or widget ID and pointer for each widget type we will be using. This is required by the library. Each widget ID has to be a unique number. It does not matter what the number is, as long as it is unique among all the other IDs. Below you'll see the ID declaration for a slider widget, five button widgets, and an edit box widget, as well as a pointer declaration for each widget type:

```
#define ID_SLD1 69   // Slider
#define ID_1_BTN 68  // Button
#define ID_2_BTN 67  // Button
#define ID_3_BTN 66  // Button
#define ID_4_BTN 65  // Button
#define ID_5_BTN 64  // Button
#define ID_MYEDITBOX 101 // Edit Box

EDITBOX *pEb;        // declare edit box pointer
BUTTON *pBtn;        // declare button pointer
SLIDER *pSlider;     // eclare slider pointer
```

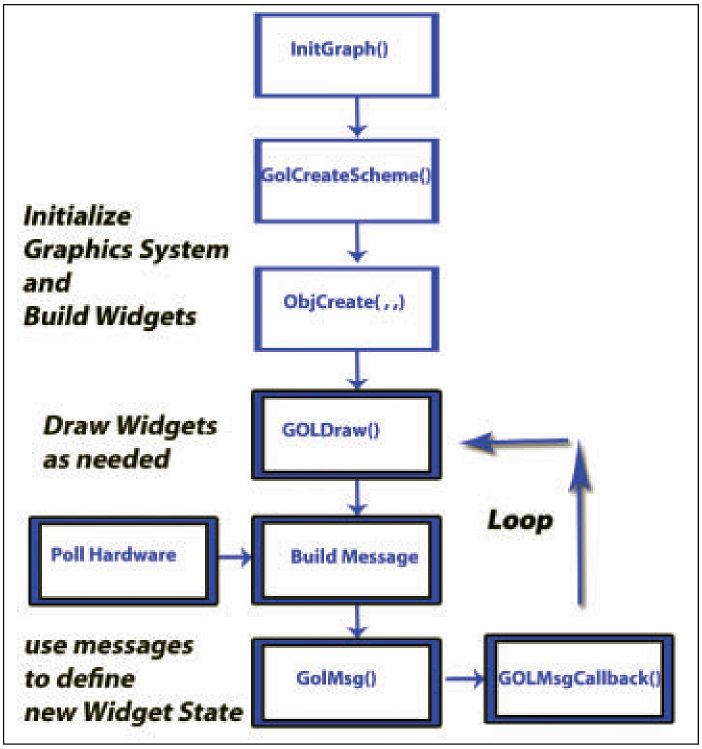


FIGURE 4. Widget operation.

Each widget has its own rendering scheme. These rendering schemes make sure that the widget — when drawn — gives an accurate graphic representation for the object it is trying to emulate. The schemes support full color and a 3D-like appearance using shadowing. Scheme pointers like those shown for the slider, button, and edit box are required by the library before creating widgets:

```
GOL_SCHEME *pSchemeSLD, *pSchemeBTN,*pSchemeEb;
```

Now, we have the project set up with all the required pointers and IDs. What's next? The library steps are shown next. We first initialize the library as shown, create our new schemes, and then create the actual widgets:

```
InitGraph ();         // initialize graphics
                      // module
GOLInit ();           // Initialize graphics
                      // library
GOLFree ();           // Clear GOL Heap
CreateSchemes ();     // build schemes for
                      // different widgets
CreateWIDGETS ();     // create necessary widgets
                      // for application uses
                      // ObjCreate ()
```

Within CreateSchemes (), we bundle all the different scheme creations. A button scheme creation is shown as an example:

```
pSchemeBTN-> Color0 =BLUE;
pSchemeBTN->Color1 =LIGHTBLUE;
pSchemeBTN->TextColor0 =WHITE;
pSchemeBTN->TextColor1 =BLACK;
pSchemeBTN->CommonBkColor=WHITE;
pSchemeBTN->EmbossLtColor= LIGHTBLUE;
pSchemeBTN->EmbossDkColor= DARKGRAY;
pSchemeBTN->pFont = (void *) &Arial_Narrow;
```

Within CreateWIDGETS (), we bundle all the different widget creations. Here's an example of a button creation:

```
BtnCreate (   ID_2_BTN,       // ID
           33,0,63,30,8,     // position,
                             // dimension and
                             // radius
           BTN_DRAW,         // state - display
                             // by GOLDraw ()
          NULL,              // bitmap (none)
          “D2”,              // text on button
           pSchemeBTN        //scheme   );
```

At this point, we can simply draw the widgets with the following library call:

```
GOLDraw ();            // library call to render
                       // widget on screen
```

Interacting With Widgets

The widget display at this point (although very cool) would be fairly static. Note in the Create example, there is a state. GOLDraw () draws only those widgets on the display whose state has been set to draw. This state was set during widget creation. Once drawn, GOLDraw () automatically resets this state so drawing — so far — only occurs once after widget creation.

Widgets are sophisticated graphic objects that support a variety of states to emulate a well assigned component behavior. For example, a button has the states press and release; the slider widget has the state slide forward and backward; all these widgets have focus and unselect. These states — in combination with draw — allow GOLDraw () to render a more dynamic widget behavior. However, what tells GOLDraw () the current widget state? This is where the magic occurs.

To make things more dynamic, the library supplies additional library functions to report those system changes to the library to affect a widget redraw and state change, while at the same time providing a call back function that coordinates a change in the user environment (coinciding with the widget change). These additional functions are GOLMsg () and GOLMsgCallBack ():

```
GOLMsg ();     // parse message from system to
               // determine effect widget
GOLMsgCallBack (); // respond to widget change
                   // and accompanying system
                   // change
```

Let's put the whole thing together. **Figure 4** captures the entire flow. We start off with the widget setups (covered earlier) and then enter a continuous loop that invokes GOLDraw (), a system specific poll/message build function, and then GOLMsg () and GOLMsgCallBack ().

The system specific poll/message build function is outside the library because it is application-specific, but interacts with the library through a standard message format. This message is passed to GOLMsg () which checks the message to determine what widget is affected for redraw and the state change. GOLMsg () does a translation of the original message for the specific widget and then invokes GOLMsgCallBack (). GOLMsgCallBack () is the opportunity for the user to coordinate any system updates coinciding with the widget redraw on the screen. This library feature allows the system to respond in conjunction with the widget change, with any proper peripheral or I/O changes. The total flow diagram is shown in **Figure 4**.

The Message Structure

The message structure is the way in which application-specific code that monitors the state of the system hardware passes information (via GOLMsg ()) to the graphic library affecting the widgets. The library, in turn, responds by isolating the affected widget(s) for redraw, and then passes a translated message back to the user (via GOLMsgCallBack ()) to optionally allow the user to respond to the widget redraw with a specific system application action.

The library GOL_MSG structure has two forms: one for a touchscreen and the other for a keyboard. Since our system does not support touchpads (no touchpad capability currently exists with the 4D color module), we will be limited to a keyboard. The GOL_MSG structure and specific keyboard type definitions are shown:

```
Typedef struct
{
   BYTE   type;        // Type of input device=
                       // TYPE_KEYBOARD
   BYTE   uiEvent;     // EVENT_KEYSCAN or
                       // EVENT_CHARCODE
   SHORT   param1;     // specific widget ID.
   SHORT   param2;     // specific scan code or
                       // character code depending
                       // on uiEvent
} GOL_MSG;
```

As an example, say we are polling the condition of pushbutton #1 on the Experimenter board. This pushbutton corresponds to BUTTON ID_1_BTN in widget world. We find that this pushbutton is depressed during our poll. The message format then kicks in.

We populate the message with uiEvent = EVENT_KEYSCAN, param1 = ID_1_BTN, param2 =SCAN_CR_PRESSED and then pass it to GOLMsg (). GOLMsg () then picks up the message, understands it is for ID_1_BTN, and sets a redraw of the button to be rendered as "pressed" on the screen; it then passes this translated message indicating the widget ID and the BTN_MSG_PRESSED condition to GOLMsgCallBack (). Here, the user can look at the message and perform a system function in conjunction with the widget redraw — like lighting LED #1 on the Experimenter board.

No question the process is involved but it does work. Information about all the possible message field scan codes and event can be found through the Microchip's graphics library help discussed earlier, or Microchip's Application Note AN1227 or AN1136. Again all this is already done for you in the supplied demos.

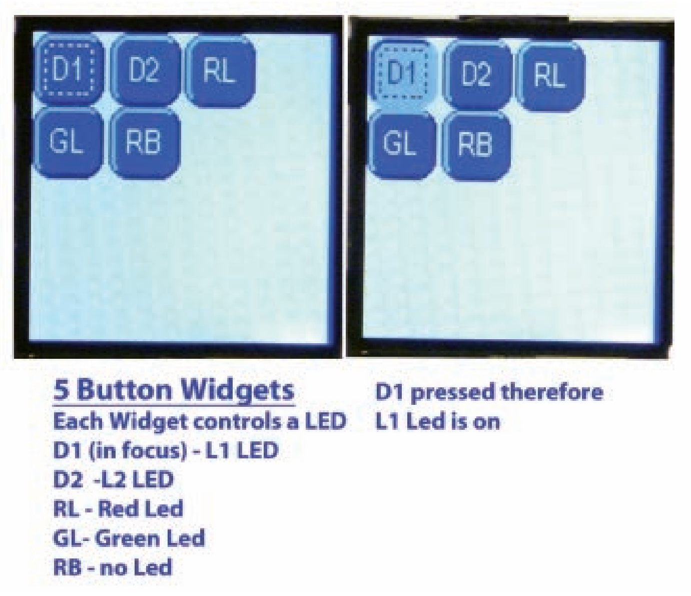


FIGURE 5. Multi-button display with focus.

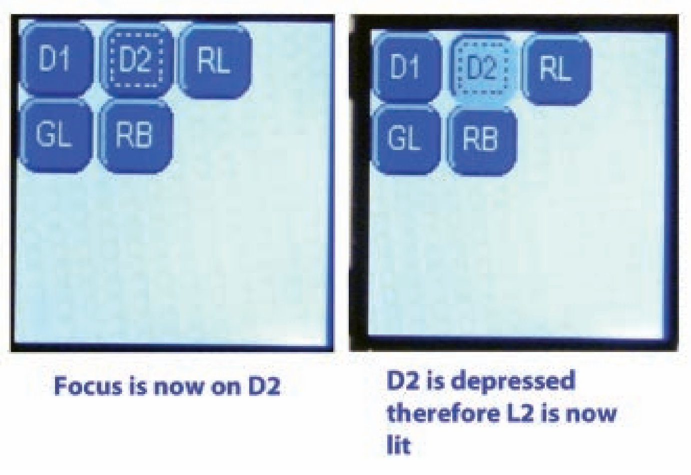


FIGURE 6. Changing focus.

Multi-Button Widget Control Using Two Pushbuttons

A neat feature of widgets is being able to display lots of pushbuttons (each of which controls a unique LED) using only two real buttons. SW1 sets focus. Every time it is depressed, it moves the focus to the next widget in a round robin fashion. Focus is indicated by a dashed line around the widget. The other button (SW2) serves as a normal button. If depressed, the current focused item is depressed.

This is a very powerful way to insert a lot of controls without necessarily using a lot of hardware. LED D1 and D2 are already either on the Experimenter. RL, GL, and RB are on the Universal display module and don't exist for the color module.

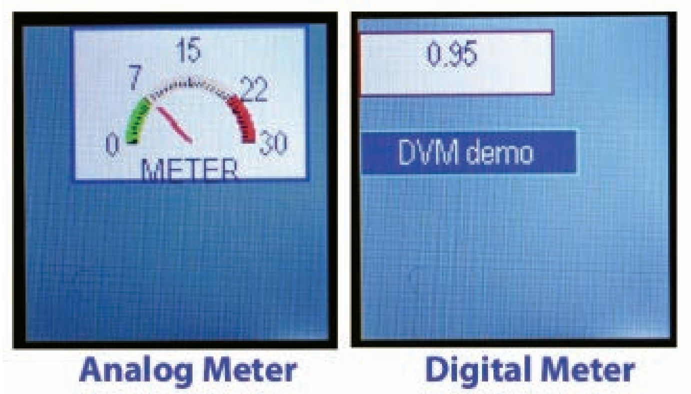


FIGURE 7. Meter demo.

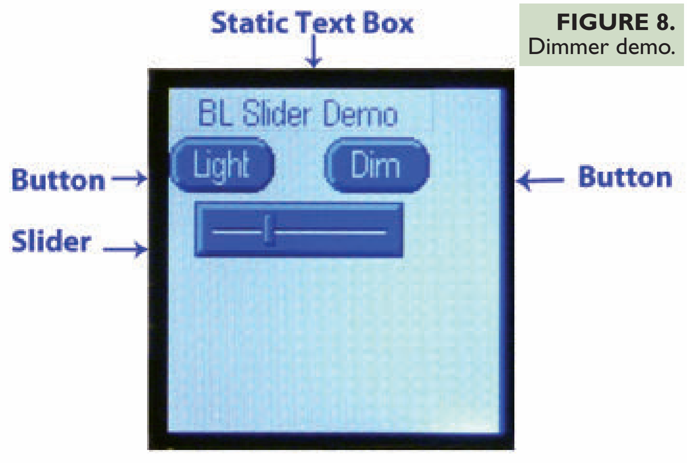


FIGURE 8. Dimmer demo.

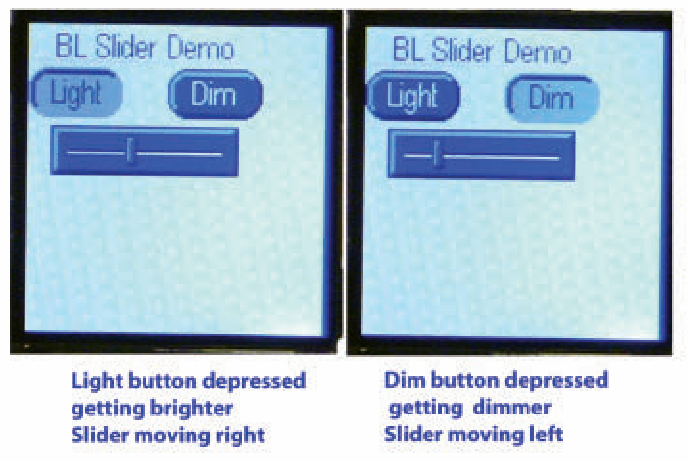


FIGURE 9. Dimmer in action.

Analog and Digital Meter Widgets

Yes, there are both analog and digital meter widgets. The analog looks like an old fashioned galvanometric meter with a moving needle over an analog scale. You simply set the scale and the resolution you want, and then feed it numeric integer values. The needle then tracks where the value falls on the scale.

The digital meter is less ominous and simply shows a multi-digital display within a frame. Again, you feed it numeric word values and a set number of digits you want displayed, and where to place the decimal point. For both display demos, we are using the PIC32 internal 10-bit ADC and digitizing a 10K potentiometer output where the potentiometer is wired between 3.3 VDC output of the EXP32 (BOT connector pin 10) and ground (BOT pin 9); the wiper of the ADC is fed into analog input channel 9 (or AN9) of the PIC32 ADC on EXP32 BOT connector pin 1. As you turn the pot, the display meter values change. Because both these widgets work without use of a keyboard message structure, in the demo code we bypass GOLMsg () and GOLMsgCallBack (), and work directly with the widget state changes and GOLDraw () in our polling code.

Slider Control of Display LED Brightness

Each of the onboard Experimenter pushbuttons (SW1 and SW2) is assigned a corresponding widget display button. SW1 is assigned display Button 1 (light) and SW2 is assigned display Button 2 (Dim). As either SW1 or SW2 is pressed or released, this action is mirrored in the widget display of these buttons. The auxiliary effect of pushing SW1 or SW2 is to move the slider1 widget left or right incrementally on each depression. SW1 moves the slider to the right, while SW2 moves the slider to the left. The slider value is used to set the duty cycle for Output Compare Module 5 (OC5) of the PIC32. The OC5 is running in a PWM (Pulse Width Modulation) mode that can directly drive an LED through a current-limited resistor. For the Universal graphics module, this is the green backlight. For the color display, you need to add your own. Tie the Experimenter JP4 pin 2 (OC5 out) to a 470 ohm resistor, to an LED anode with the LED cathode to ground. The greater the duty cycle is, the brighter the display becomes. Finally, on the display there is a static text box used to provide a title for the demo.

In **Figure 9**, we see SW1 and SW2 in action, and how the display is brightened or dimmed.

RTCC Setting Using Widgets and Keyboard

The RTCC is a 100 year clock/calendar peripheral of the PIC32. It requires that you have the X2 crystal on the Experimenter board populated with a 32 kHz tuning crystal (Jameco part #14584) in order to work. This demo uses a PS/2 keyboard to input data to the edit box, and to select and activate a button widget to set the clock. Other buttons are thrown in for fun to control LEDs.

The demo uses focus to select the button, and disables the time set button once the time is set. Once this happens, it is automatically shown in the edit box as a running clock. The edit box is used to enter time numbers, backspace to clear, and return/enter the final time. The right arrow is used to change focus.

RGB LED Color Control Using Three Sliders for PWM

Okay. Instead of just one slider, how about three? Each slider will control a unique OC output of the PIC32. Slider 1 will control OC2; Slider 2 will control OC3; and finally, Slider 3 will control OC4 — for three independent PWM outputs in total. Each PWM is assigned to a pin of the RGB LED diode (SparkFun #COM-09246). In theory, we can generate any of 65K colors, with Slider 1 (BOT pin 7) driving the red pin through a 470 ohm resistor; Slider 2 (JP2 pin 1) driving the green pin through a 470 ohm resistor; and Slider 3 (JP2 pin 2) driving the blue pin through a 470 ohm resistor. The RGB LED cathode is tied to ground. The keyboard is used to set focus on which slider is active by hitting the return key. The keyboard up/down arrows are used to increment and decrement the specific slider.

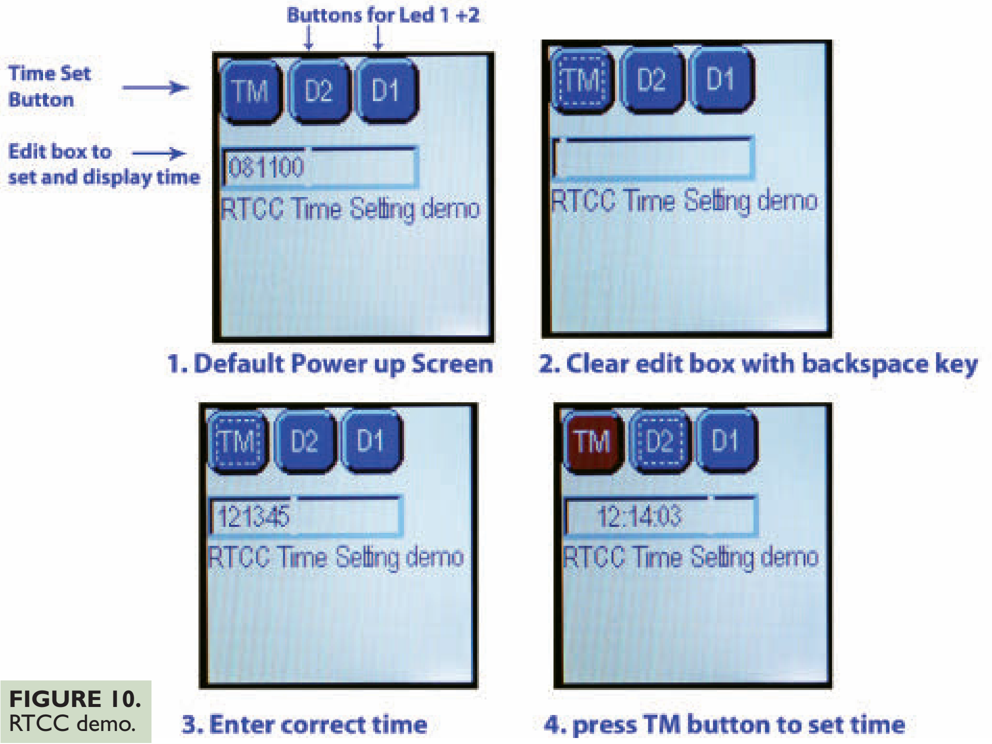

Buttons for Led 1 +2
Time Set Button
Edit box to set and display time
TM
D2
D1
081100
RTCC Time Setting demo
1. Default Power up Screen
2. Clear edit box with backspace key
121345
3. Enter correct time
12:14:03
4. press TM button to set time

FIGURE 10. RTCC demo.

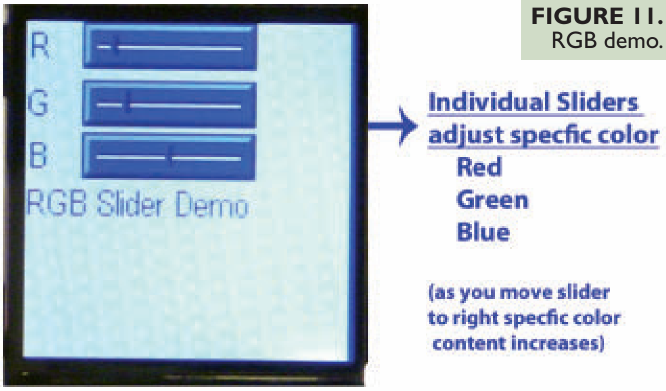

R
G
B
RGB Slider Demo
Individual Sliders adjust specfic color
Red
Green
Blue
(as you move slider to right specfic color content increases)

FIGURE 11. RGB demo.

Primitives Demo

This library feature was covered more extensively in the June '11 article. Basically, the demo executes an outline of the display, crosses many lines at the center, circles those cross points, fills in those circles, and then does a multi-level rectangular display. Finally, a font and bitmap are completed, and the backlight is configured from green to red.

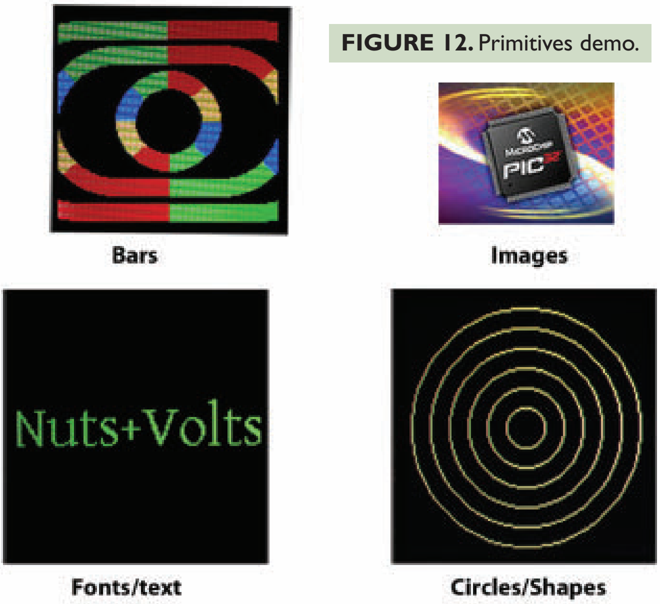

Bars
Microchip PIC32
Images
Nuts+Volts
Fonts/text
Circles/Shapes

FIGURE 12. Primitives demo.

In Summary

We have taken a closer look at widgets and have hopefully provided a good foundation to help you in using this powerful capability. Take time to review the demo source code, and be sure to access the Microchip website for additional information.

We also introduced a new color module for the Experimenter. The monochrome Universal graphics module also exists here still, but color can really show off the full widget power! Until next time, happy 32-bit processing! **NV**

The new Color Graphics Display module to go with this article can be purchased online from the *Nuts & Volts* Webstore at www.nutsvolts.com or call our order desk at 800-783-4624.

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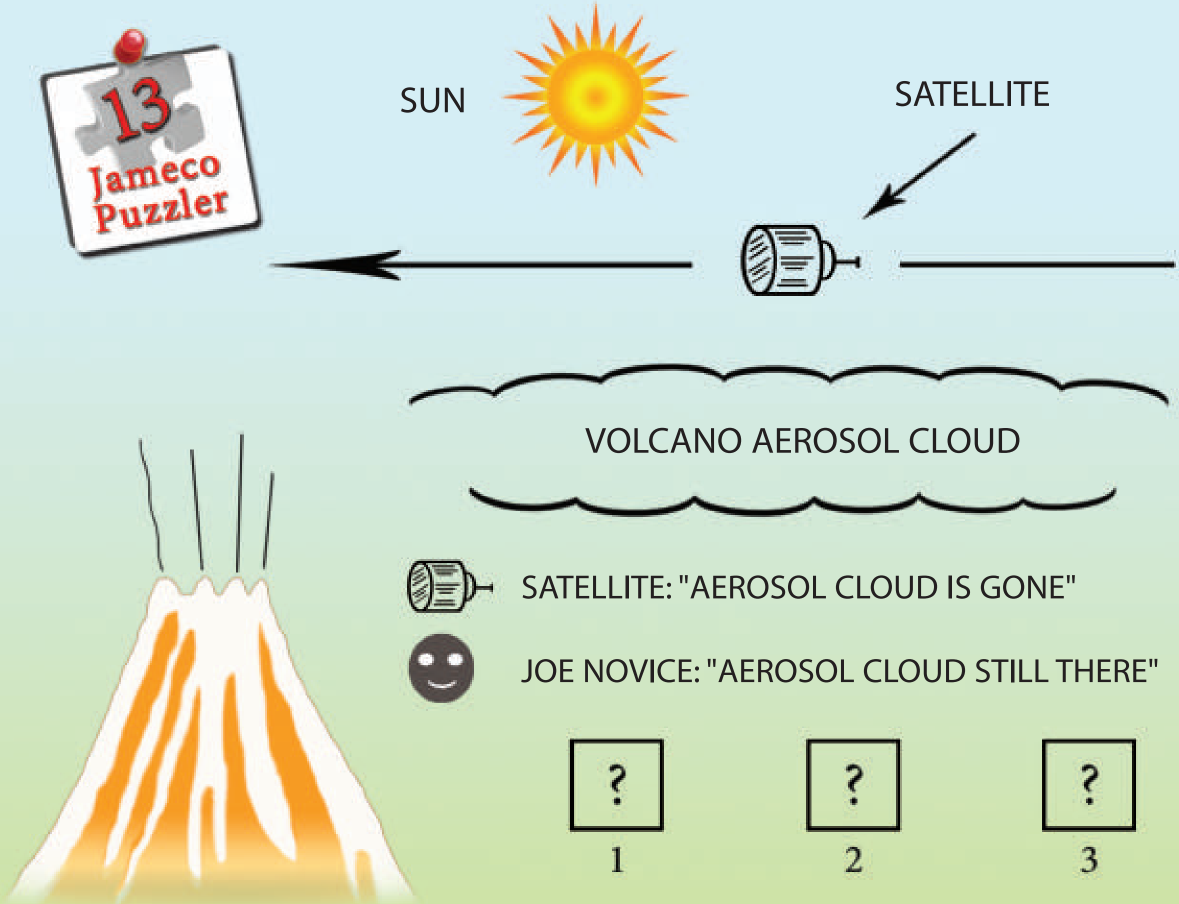
13
Jameco Puzzler
SUN
SATELLITE
VOLCANO AEROSOL CLOUD
SATELLITE: "AEROSOL CLOUD IS GONE"
JOE NOVICE: "AEROSOL CLOUD STILL THERE"
?
1
?
2
?
3
VOLCANO

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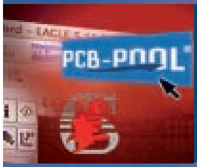

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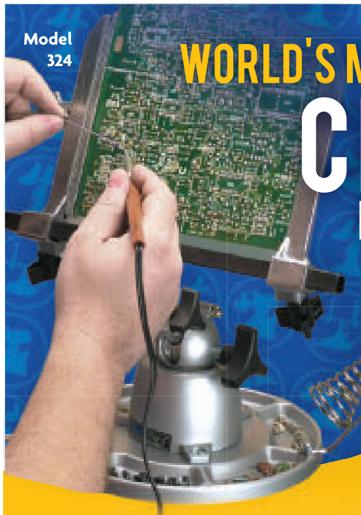

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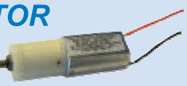

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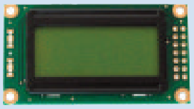

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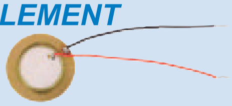

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#45 SMILEY'S WORKSHOP

C PROGRAMMING - HARDWARE - PROJECTS

by Joe Pardue

Chaser Light Marquee – Part 1

Follow along with this series! Joe's book & kits are available at www.nutsvolts.com

Discuss this article in the *Nuts & Volts* forums at http://forum.nutsvolts.com.

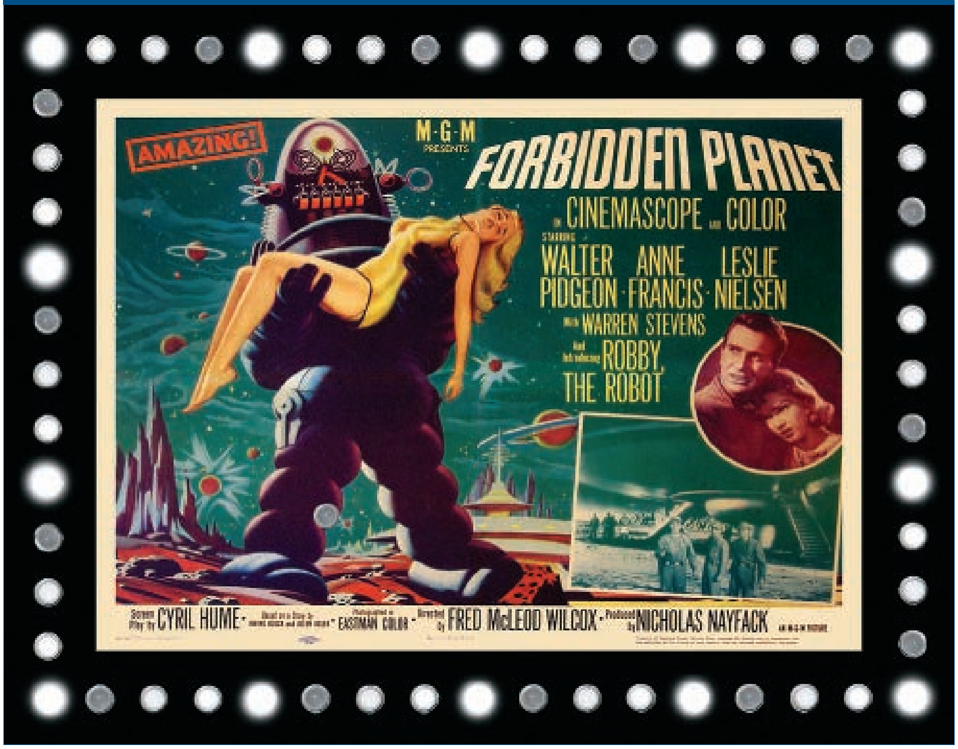
Recap

You may have noticed that recently these workshops have had a split personality with a theory part on some difficult topic in C, and then a lab part with some sort of related hardware project with shiny lights (ohhh ... s-h-i-n-e-y!). We will continue this for a while until we complete these difficult (but important) C topics. Last month, we had some fun with the simple chaser lights board (available from *Nuts & Volts*) and we had less fun (maybe even some pain) with an introduction to C pointers. This month, we are going to have some fun by expanding our chaser lights into a movie theater style marquee frame (**Figure 1**), and we are going a little deeper with C pointers.

Introducing Some Hard Stuff

We are getting into some C programming concepts that novices find most difficult to get their heads around. These include pointers, arrays, enums, unions, and structures. While these can be difficult at first, they are so important to using C to its fullest power that I encourage you to stick with it for the next several months while I do my best to make these concepts comprehensible. I am going to use a lot of repetition in these discussions — going at things from different angles and over-explaining things to such a degree that some readers may lament my overkill approach, while others may find that they really needed to see the same thing from different angles in order to finally get it.

■ FIGURE 1. DIY marquee frame mockup.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STARRING
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ANNE FRANCIS
LESLIE NIELSEN
WITH WARREN STEVENS
AND INTRODUCING ROBBY, THE ROBOT
SCREEN PLAY BY CYRIL HUME
EASTMAN COLOR
DIRECTED BY FRED McLEOD WILCOX
PRODUCED BY NICHOLAS NAYFACK

I will also be adding another duplication. I am going to use both the standard Atmel AVR programming tools — AVRStudio, avrlibc, and avrdude — and I'm going to show the same concepts with a free PC based C tool: Pelles C. By seeing these concepts on two different systems, I'm hoping that this will further reinforce your learning. If you have been following my discussions of C so far (and continue to follow them for the next several months), you may then consider that you have had a good solid introduction to the C programming language.

'Best' Way to Learn About C Pointers, Arrays, Structures, Etc. ...

I once got into an argument with a bunch of folks on AVRFreaks about the best way to start learning C. There were about 10 folks involved with at least 20 different opinions. I asserted that since the novice was going to be using C in the AVR on some sort of embedded system, then that embedded system would be the best platform to start with. Several other folks argued that starting on a PC with the easier user interface was a better idea since it gave immediate feedback. I poo-pooed that stating that using C on a PC in the 21st century was stupid since almost nothing on a Windows PC is written in C anymore. And bla bla bark bark ... the argument finally petered out with no consensus.

Well, I've changed my mind. Some C techniques are pretty hard to learn, and having the extra hassle of an AVR development system to deal with can distract people from learning the C syntax. For instance, I was trying to refresh my recollections on how to pass a two-dimensional array to a function in C and after a couple of passes at it using my BreadboArduino (available from *Nuts & Volts*), I got frustrated not knowing if there was a hardware problem on the breadboard, a software problem with AVRStudio, or a wetware problem with my brain. So, I got out Pelles C and ran a few quick tests and figured out the correct way to do things in C before applying that correctness to the rats nest of my breadboard. (Yes, it was a wetware problem.) I figured if I am going to use it to make my life easier, then it is only fair to suggest you do likewise.

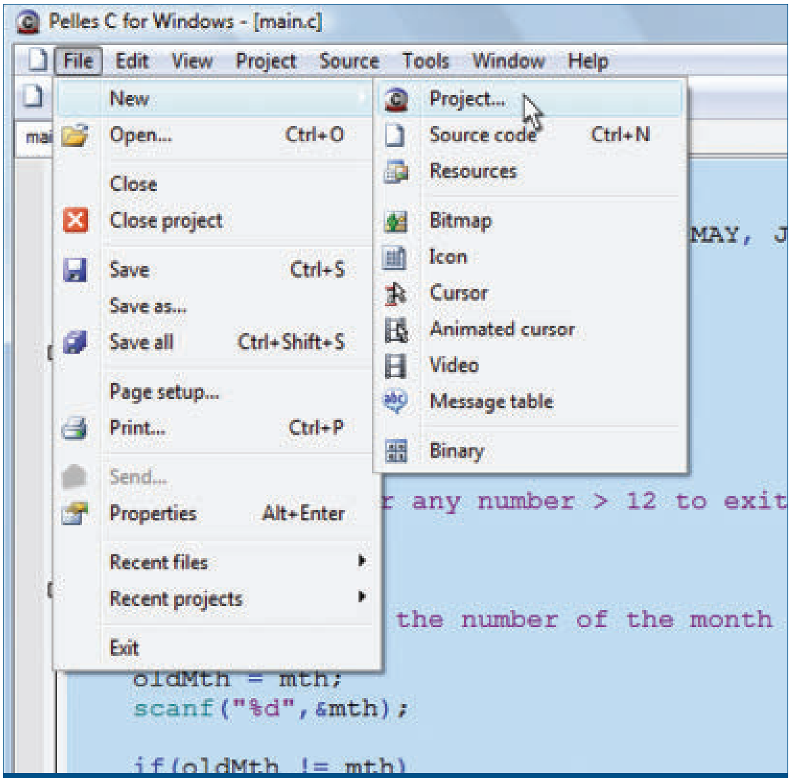
You can get Pelles C at **www.smorgasbordet.com/pellesc**. It is free, and once you figure out how to enlarge the print to a readable size, it is very easy to use [Tools\Options\Source\Fonts\Size]. So, for the discussion on further introducing pointers, let's start with Pelles C. [BTW, we were first introduced to Pelles C in Smiley's Workshop 23: AVR Memory Part 1, Introduction in the June '10 issue — some of which is repeated here so you don't have to dig it out.]

Using Pelles C

The book *C Programming Language* by Brian W. Kernighan and Dennis M. Ritchie starts with the classic 'hello, world' program:

```
#include <stdio.h>

main()
{
        printf(“hello, world\n”);
}
```

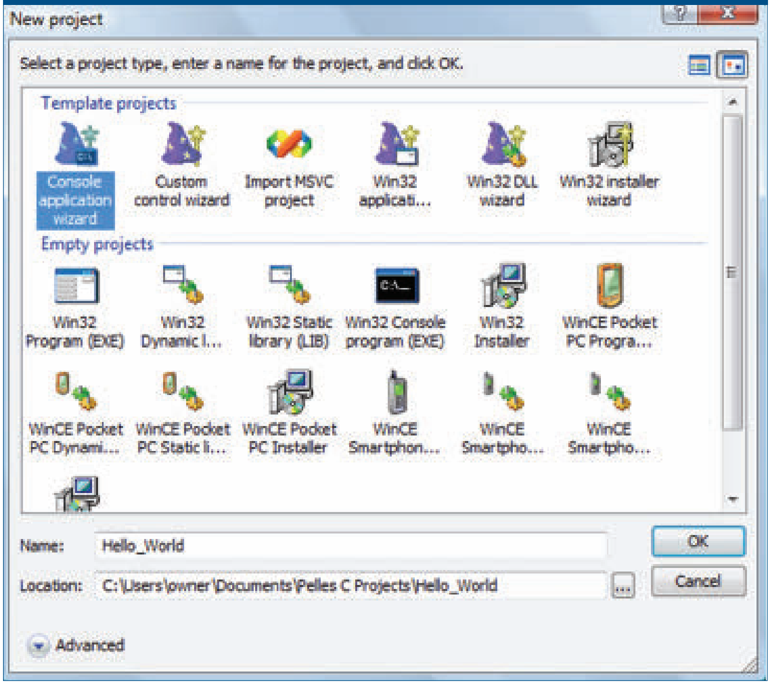

Pelles C for Windows - [main.c]
File
Edit
View
Project
Source
Tools
Window
Help
New
Open...   Ctrl+O
Close
Close project
Save   Ctrl+S
Save as...
Save all   Ctrl+Shift+S
Page setup...
Print...   Ctrl+P
Send...
Properties   Alt+Enter
Recent files
Recent projects
Exit
Project...
Source code   Ctrl+N
Resources
Bitmap
Icon
Cursor
Animated cursor
Video
Message table
Binary
mai
MAY, J
r any number > 12 to exit
the number of the month
oldMth = mth;
scanf("%d",&mth);
if(oldMth != mth)

■ FIGURE 2. Open project in Pelles C.

Interestingly, Pelles C has a wizard application that creates a version of this program as a template for writing other programs.

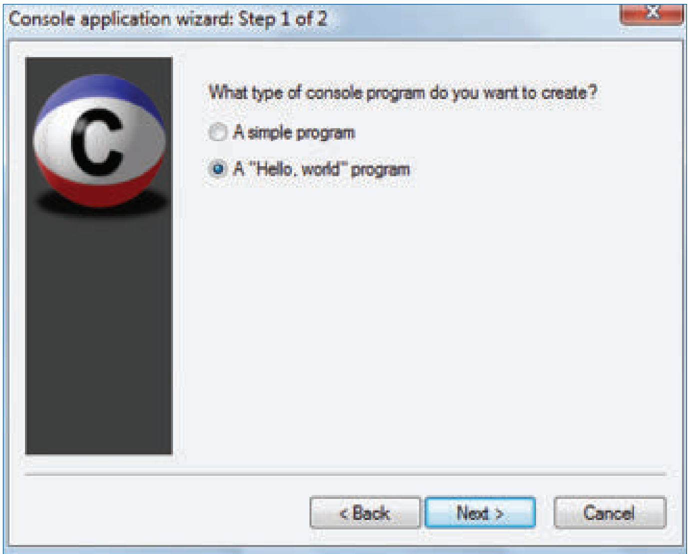
Open Pelles C (**Figure 2**), click on the File menu, and select New\Project. **Figure 3** shows the resulting window with 'Console Application Wizard' highlighted and

■ FIGURE 3. Pelles C new project.


New project
Select a project type, enter a name for the project, and click OK.
Template projects
Console application wizard
Custom control wizard
Import MSVC project
Win32 applicati...
Win32 DLL wizard
Win32 installer wizard
Empty projects
Win32 Program (EXE)
Win32 Dynamic l...
Win32 Static library (LIB)
Win32 Console program (EXE)
Win32 Installer
WinCE Pocket PC Progra...
WinCE Pocket PC Dynami...
WinCE Pocket PC Static li...
WinCE Pocket PC Installer
WinCE Smartphon...
WinCE Smartpho...
WinCE Smartpho...
OK
Cancel
Advanced

Name: Hello_World

Location: C:\Users\owner\Documents\Pelles C Projects\Hello_World

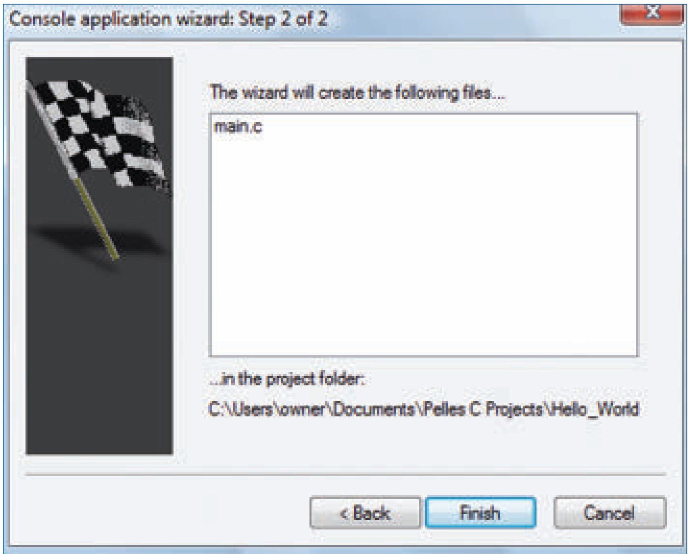

Console application wizard: Step 1 of 2
< Back
Next >
Cancel

What type of console program do you want to create?

○ A simple program

● A "Hello, world" program

■ FIGURE 4. Pelles C console wizard step 1.


Console application wizard: Step 2 of 2
< Back
Finish
Cancel

The wizard will create the following files...

main.c

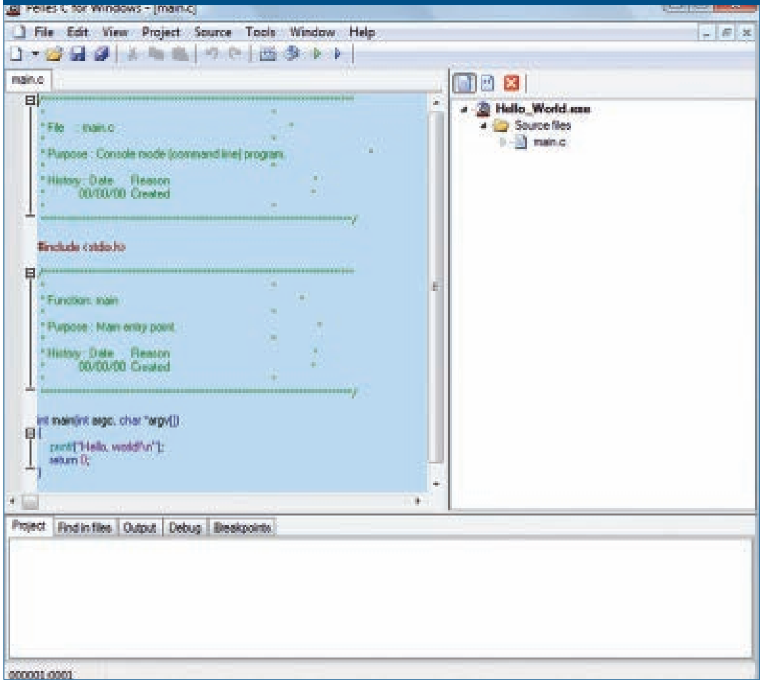
...in the project folder:

C:\Users\owner\Documents\Pelles C Projects\Hello_World

■ FIGURE 5. Pelles C console wizard step 2.

Hello_World typed into the 'Name:' field. Click OK and you'll see the window shown in **Figure 4**. Check the 'A "Hello, world" program. Yes, the Hello World program is so basic that it is included for you! Click Next, and you'll see the window in **Figure 5**. Now click the 'Finish' button. As if by magic, Pelles will write your first Hello World program for you as shown in **Figure 6**. Next, click the 'Compile' button and the 'Execute' button; you'll see the console output shown in **Figure 7**.

■ FIGURE 6. Pelles C Hello World.


Pelles C for Windows - [main.c]
File
Edit
View
Project
Source
Tools
Window
Help
main.c
Hello_World.exe
Source files
main.c
Project
Find in files
Output
Debug
Breakpoints
000001:0001

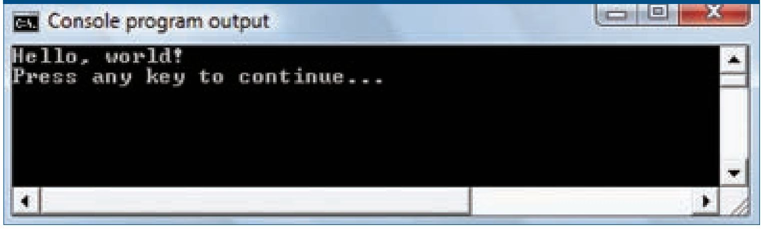
```
/****************************************************************
 *                                                              *
 * File    : main.c                                             *
 *                                                              *
 * Purpose : Console mode (command line) program.               *
 *                                                              *
 * History : Date      Reason                                   *
 *           00/00/00  Created                                  *
 *                                                              *
 ****************************************************************/

#include <stdio.h>

/****************************************************************
 *                                                              *
 * Function: main                                               *
 *                                                              *
 * Purpose : Main entry point.                                  *
 *                                                              *
 * History : Date      Reason                                   *
 *           00/00/00  Created                                  *
 *                                                              *
 ****************************************************************/

int main(int argc, char *argv[])
{
    printf("Hello, world!\n");
    return 0;
}
```

■ FIGURE 7. Pelles C console Hello World.


Console program output

```
Hello, world!
Press any key to continue...
```

Whoa! That's so easy that it almost makes us forget that there are some not so easy things going on under the hood. Our job is to learn about those not so easy things.

Note on Porting Pelles C Code to AVRStudio

You may have noticed that the program generated by Pelles C looks a bit different from the version in K&R (C programming language; Brian Kernighan and Dennis Ritchie) and from what you would use with AVRStudio. First, there are the parameters for the main function. Also, the main function returns 0 as shown below:

```
// Using main with an Operating System
int main(int argc, char *argv[])
{
     printf("Hello, world!\n");
     return 0;
}
```

We typically don't use either of these in embedded systems because they imply an operating system that we don't have for the small embedded systems we are using. The 'argc' and 'argv' parameters in main() are input that the OS sends to the main() function when invoking the C program; the 'return' is what is returned when the program exits. A system with an OS can run a variety of C programs, but an embedded system without an OS just starts up and runs a single program until power down. So, sending it parameters and then waiting for a return value from it makes no sense. For embedded systems, we usually run the code in some sort of infinite loop in the main() function. If we write the code for an AVR using AVRStudio, we'd drop the argc, argv, and return:

```
// Using main with out an Operating System
void main(void)
{
     printf("Hello, world!\n");
}
```

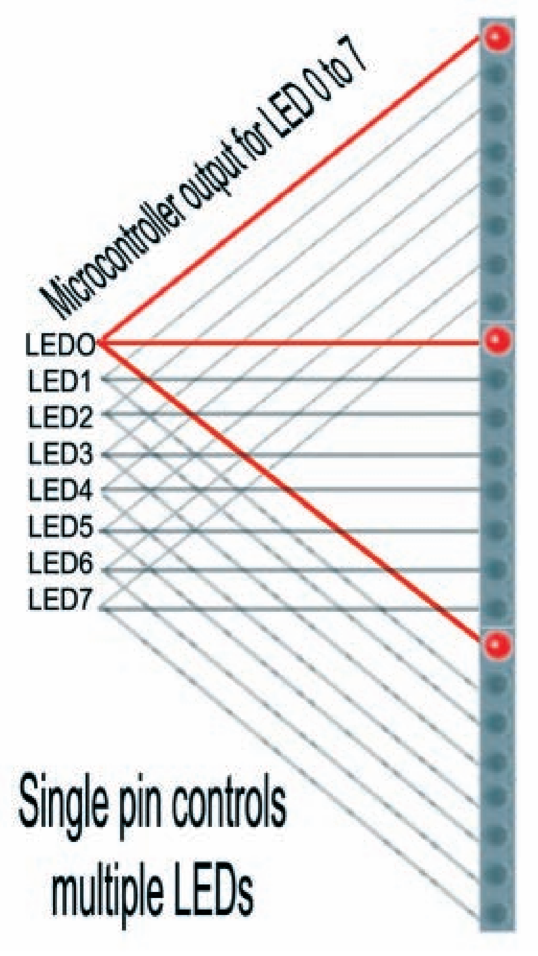
Keep this in mind; we should be able to port code directly from Pelles C to AVRStudio.

Getting Started With Pointers

Last month, we were given a brief introduction to pointers and learned the following:

- In C, a pointer is a data type with a value of an address that refers directly to (points to) another value stored elsewhere in memory.
- A pointer is said to reference that value, and using a pointer to get the value is called dereferencing.
- A pointer is like any other variable in that it has an address, and that there is data stored at that address. [That data is an address.]
- It is different from other variables in that C knows that a pointer is to be used to store the address of another variable.
- At the memory address of a pointer, the memory address of another variable is stored.
- By dereferencing a pointer, C gets the address stored at the pointer's address and uses that stored address to access the data stored at the address indicated.
- A variable has an address and data is stored at that address. A pointer has an address and the address of another variable is stored at that address.

■ FIGURE 8. Multiple LED output.


Microcontroller output for LED 0 to 7
LED0
LED1
LED2
LED3
LED4
LED5
LED6
LED7
Single pin controls multiple LEDs

That list had some redundant concepts in it, but these concepts are so important that repetition may help some folks get them. So, let's be even more repetitive because I've never felt comfortable explaining pointers since I still tend to mess them up. I remember how many false starts I had trying to learn them. On the surface, they are simple: A pointer is a memory location containing the address of another memory location.

In C, a pointer is a data type for a variable intended to hold the address of another variable. You tell C that a data type is a pointer by marking it with an asterisk '*.' So, when you define char *myCharPointer, you are telling the C compiler that myCharPointer is the address of a character. When you define it, it does not contain an address of a character, but must have that address given to it by an assignment operation. You extract the address of a character from a char variable by using the '&' address-of operator. So, to set the pointer to contain the address of a character you would first define a pointer to a character, then put the address of a character as follows:

```
// pointer declared, but not set to anything
char *myCharPointer;

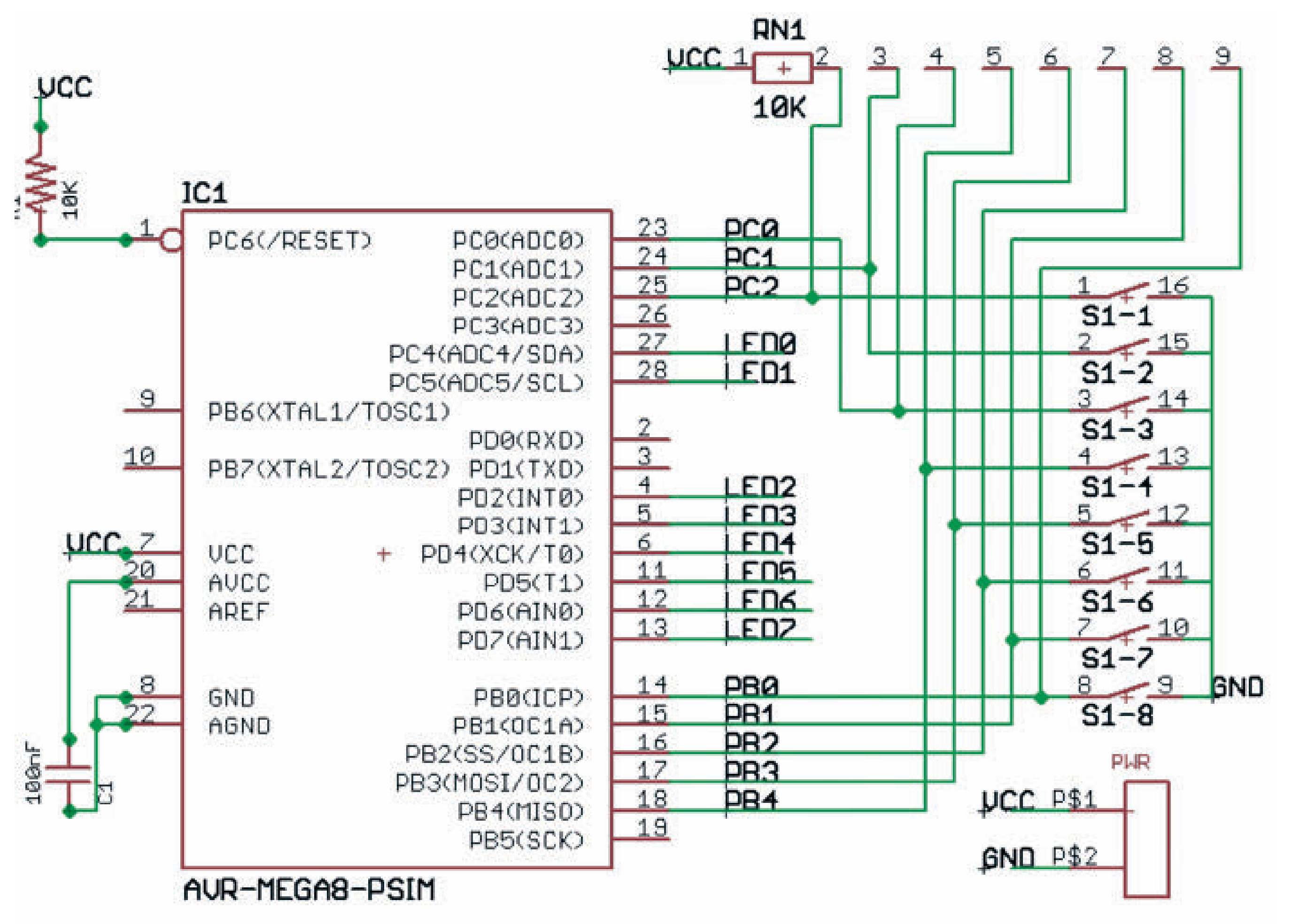
// char variable myChar declared and set to
// the char ‘Sa’
char myChar = ‘S’;

// myCharPointer is set to contain the address
// of myChar
myCharPointer = &myChar;
```

This may look simple but implementation can be the killer. Cliff Lawson — the number one poster on AVRFreaks — manages large software projects with 50+ programmers and he says that 50% of the bugs come from pointers. And these guys know what they are doing. So, expect to have to approach learning about pointers many times and from many directions. The best thing I can suggest to help you learn to safely use pointers is to write small pieces of code and thoroughly test them before including them in larger pieces of code.

When you get experienced enough that pointers seem second nature, that's when you will start to get into real trouble. You'll get bugs that drive you, well ... buggy, but that is part of the price of admission to C programming of microcontrollers. (Hey! What a nice title for a book – and coincidentally, a book that you can get from *Nuts & Volts* along with an excellent hardware projects kit to give yourself a leg up on this C stuff.)

We need to leave room in this article so we can get started on the chaser light marquee project,


VCC
10K
IC1
RN1
VCC 1
2 3 4 5 6 7 8 9
10K
PC6(/RESET)
PC0(ADC0)
PC1(ADC1)
PC2(ADC2)
PC3(ADC3)
PC4(ADC4/SDA)
PC5(ADC5/SCL)
PB6(XTAL1/TOSC1)
PD0(RXD)
PB7(XTAL2/TOSC2)
PD1(TXD)
PD2(INT0)
PD3(INT1)
VCC
PD4(XCK/T0)
AVCC
PD5(T1)
AREF
PD6(AIN0)
PD7(AIN1)
GND
PB0(ICP)
AGND
PB1(OC1A)
PB2(SS/OC1B)
PB3(MOSI/OC2)
PB4(MISO)
PB5(SCK)
AVR-MEGA8-PSIM
100nF
C1
PC0
PC1
PC2
LED0
LED1
LED2
LED3
LED4
LED5
LED6
LED7
PB0
PB1
PB2
PB3
PB4
S1-1
S1-2
S1-3
S1-4
S1-5
S1-6
S1-7
S1-8
GND
PWR
VCC P$1
GND P$2

■ FIGURE 9. Schematic for the LED controller.

so let’s finish the theory with a Pelles C program to show a simple use of pointers. Next month, we’ll look more deeply at this example and expand on it some:

```
#include <stdio.h>

int main()
{
  // declare a char variable and set it to ‘S’
  char myVariable = ‘S’;
  // define anotherChar to hold the data ‘A’
  char anotherVariable = ‘A’;

  // declare a variable that will contain the
  // address of a char
  char *myPointer;

  printf(“Begin with myVariable = %c\n”,
  myVariable);
  printf(“and anotherVariable = %c\n\n”,
  anotherVariable);

  // set myPointer to the address of myVariable
  myPointer = &myVariable;

  // load anotherChar with the char pointed to
  // by myPointer
  anotherVariable = *myPointer;

  printf(“End with myVariable = %c\n”,
  myVariable);
  printf(“and anotherVariable = %c\n\n”,
  anotherVariable);
}
```

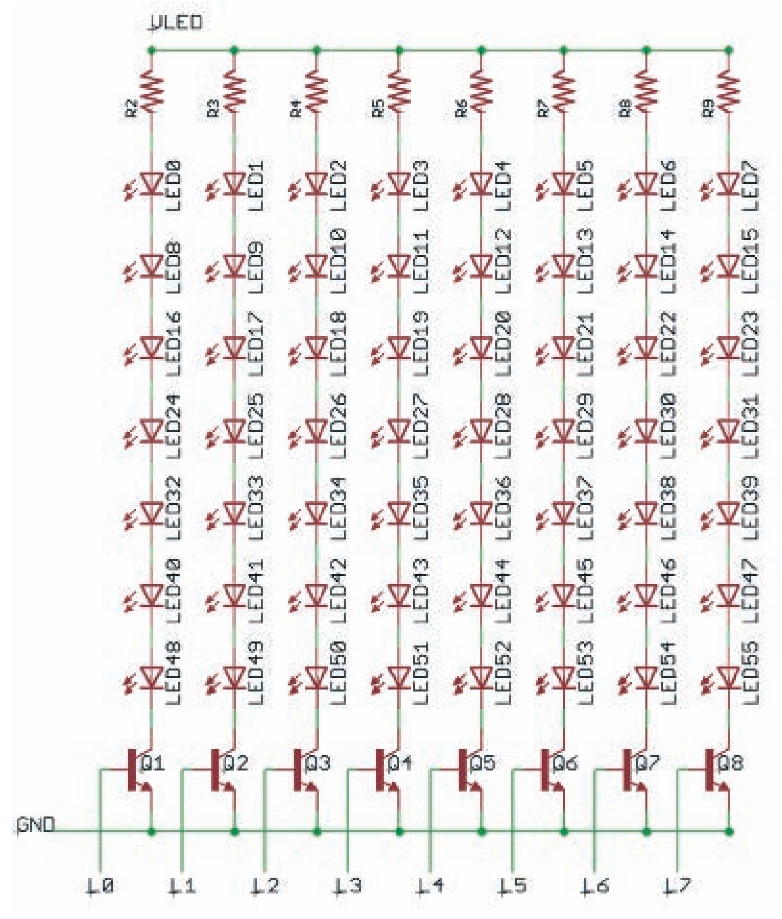
Run this program and then get out the pencil and paper computer to make sure you really understand what is going on.

Lab: Marquee Chaser Lights

Time for an antidote to C pointers. Have you ever wanted one of those chaser light movie poster frames for your very own home theater? Well, I have and they cost hundreds (even thousands) of dollars each. So being DIYers, why not build one? **Figure 1** shows a mockup of a chaser lights marquee frame for an old-style movie lobby-card. This month, we will get started on this project and finish it off next month. Our goal here is not just to have something to hang on our wall, but to learn how to use a few control points for a whole string of LEDs arrayed like the chaser lights on a theater marquee.

When you look at a chaser light marquee, you might wonder how on earth do they get enough I/O lines to run all those lights. Well, there is a trick. They only use a few control lines and they gang a bunch of lights onto each control point as shown in **Figure 8**. While this illustration shows only three LEDs being controlled from a single control point, the only practical limit to how many of these eight light groups you control is how much current you've got and what kind of devices you use to control that current.

If we wanted to, we could put a few million searchlights around the US border and provide quite a show for visiting aliens – and it could be controlled by a single AVR! The control itself only needs to drive a switch (usually some sort of transistor or relay) and that switch then powers all the lights. So, we can have eight control lines and then if we choose to have 56 lights, we can link them as seven blocks of eight LEDs each, arranged end to end. This is what we do with the marquee frame project. However, instead of driving them in parallel as shown in **Figure 8**, I've chosen to stack them such that each LED is driven in series rather than parallel. [See **Figure 9** for the schematic.] The parallel arrangement makes a better explanatory illustration, but stacking them in series as shown in **Figure 10** makes better electrical sense, as you'll see in a minute.


VLED
R2
R3
R4
R5
R6
R7
R8
R9
LED0
LED1
LED2
LED3
LED4
LED5
LED6
LED7
LED8
LED9
LED10
LED11
LED12
LED13
LED14
LED15
LED16
LED17
LED18
LED19
LED20
LED21
LED22
LED23
LED24
LED25
LED26
LED27
LED28
LED29
LED30
LED31
LED32
LED33
LED34
LED35
LED36
LED37
LED38
LED39
LED40
LED41
LED42
LED43
LED44
LED45
LED46
LED47
LED48
LED49
LED50
LED51
LED52
LED53
LED54
LED55
Q1
Q2
Q3
Q4
Q5
Q6
Q7
Q8
GND
L0
L1
L2
L3
L4
L5
L6
L7

■ FIGURE 10. Schematic LED array.

How to Use It

Driving Seven LEDs in Series

The LEDs I use in this project drop 3.4 volts and are plenty bright at 20 milliamps. If we stack them as shown in **Figure 10** and we use 30 volts, then we can drop 7 x 3.4 = 23.8 volts. The transistors will drop another .7 volts, so our total drop is 24.5 volts, leaving us with 5.5 volts to control the current. This requires about a 275 ohm resistor. DON'T follow what I just said until you measure the voltage drop on your LEDs since it may well be different. [I used white, but colored LEDs tend to drop much less voltage.] Our tradeoff here is that we need a higher voltage, but we only have to use a single resistor for each of the LED channels. Having eight resistors instead of 56 (as we'd need if we did the LEDs in parallel) saves us a bunch of work. [**NOTE**: I may refine these values next month, so don't rely on them too much.]

You might question if the transistors are really necessary since the control line is pulling the 20 mA current to ground; what difference does it make that it starts off as 30 volts? Well, probably not one little bit. However, rather than risk some sort of screw-up during construction exposing the AVR control pins to that high a voltage, I decided not to take the risk since switching transistors are a few pennies each.

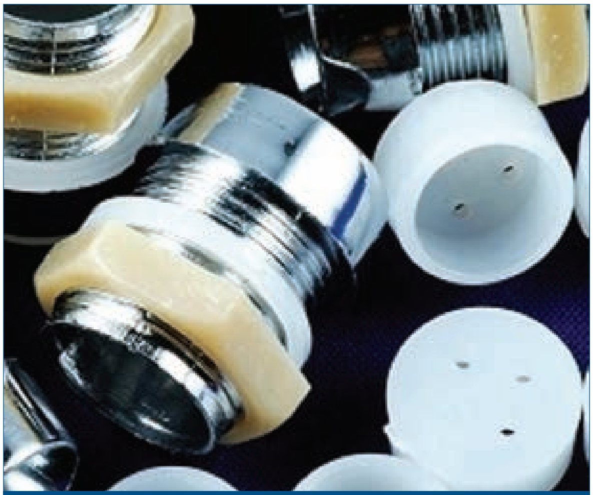
I found chrome plated plastic 10 mm LED bezels (**Figure 11**) on eBay for $20 per hundred. They aren't exactly high quality, but for twenty cents each I can't really complain. I found 100 10 mm white LEDs (**Figure 12**), also on eBay for $14. Both of these orders included free shipping from Hong Kong and took about three weeks to get here.

Theory is all well and good, but to really learn this stuff you have to get your hands on some tangible items that blink, whirr, and sometimes detonate. As a service for the readers of the Smiley's Workshop articles, we have simple and inexpensive projects kits available that can help you make it real. You can find these kits (and some darn good books) at the *Nuts & Volts* Webstore.

Item	Description
Simple chaser lights kit	Nuts & Volts
56 10 mm white LEDs	eBay
56 10 mm LED bezels	eBay
Lots of 24 AWG stranded wire	(> 50')
Frame stock	Your choice
30 volt power supply	Your junk box

Table 1. Bill of Materials.

www.nutsvolts.com/index.php?/magazine/article/april2012_SmileysWorkshop



■ FIGURE 11. The 10 mm LED bezel.

■ FIGURE 12. The 10 mm white LED.

Next month, we will grimace and dig ourselves in deeper with C pointers and we will grin and finish the chaser lights frame.

Questions? *Nuts & Volts* is hosting forums for its writers and you can find mine at **http://forum.servomagazine.com**. If you want a quick response — especially to a question not directly related to an article — you can put on your biohazard suit and start a thread on **www.avrfreaks.net**.

If you just can't wait and want to get a leg up on all this serial stuff and real C programming for the AVR (while helping support your favorite magazine and technical writer), then buy my C Programming book and Butterfly projects kit, and the *Virtual Serial Port Cookbook* using the *Nuts & Volts* magazine or their web shop. **NV**

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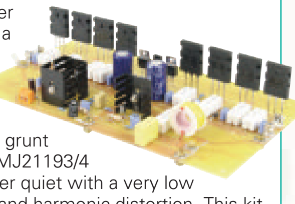
Studio 350 - High Power Amplifier

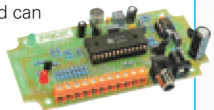
KC-5372 $126.00 plus postage & packing



The studio 350 power amplifier will deliver a whopping 350WRMS into 4ohms or 200WRMS into 8ohms. It offers real grunt using a high power MJ21193/4 transistor and is super quiet with a very low signal to noise ratio and harmonic distortion. This kit is supplied in short form with PCB and electronic components. Kit requires heatsink and (+/-) 70V power supply as described in instructions. See website for more specifications.

45 Second Voice Recorder Module

KC-5454 $25.25 plus postage & packing

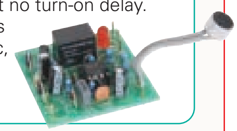


This kit has been improved and can now be set up easily to record two, four or eight different messages for random-access playback or a single message for 'tape mode' playback. Also, it now provides cleaner and glitch-free line-level audio output suitable for feeding an amplifier or PA system. It can be powered from any source of 9-14VDC.

- Supplied with silk screened and solder masked PCB and all electronic components
- PCB: 120(L) x 58(W)mm

Minivox Voice Operated Relay

KC-5172 $11.50 plus postage & packing



Voice operated relays are used for 'hands free' radio communications and some PA applications etc. Instead of pushing a button, this device is activated by the sound of a voice. This tiny kit fits in the tightest spaces and has almost no turn-on delay. 12VDC @ 35mA required. Kit is supplied with PCB electret mic, and all specified components.

- PCB: 47 x 44mm

Jacob's Ladder High Voltage Display Kit MK2

KC-5445 $31.00 plus postage & packing

With this kit and the purchase of a 12V ignition coil (available from auto stores and parts recyclers), create an awesome rising ladder of noisy sparks that emits the distinct smell of ozone. This improved circuit is suited to modern high power ignition coils and will deliver a spectacular visual display.

Kit includes PCB, pre-cut wire/ ladder and all electronic components.

- 12V automotive ignition coil and case not included
- 12V car battery, 7Ah SLA or >5Amp DC power supply required and not included
- PCB: 170 x 76mm

Warning: The Jacobs Ladder Kit uses potentially dangerous voltage.

KIT OF THE MONTH

The Super Ear

KA-1809 $20.25 plus postage & packing

Assists people who have difficulty hearing high audio frequencies, or use as an interesting education aid in the classroom. By amplifying high audio frequencies, conversations will be made clearer and you will hear sounds not normally heard such as insects or a watch ticking. Kit supplied with case, processed panels, PCB, 9V battery, and all electronic components. Headphones required.

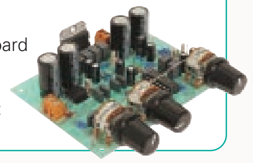
- PCB: 56 x 26mm

Note: Not a replacement for a proper hearing aid.

High Performance 12V Stereo Amplifier

KC-5495 $32.75 plus postage & packing

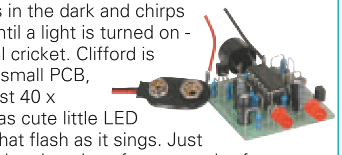
An ideal project for anyone wanting a compact and portable stereo amp where 12V power is available. No mains voltages, so it's safe as a beginner's first amp. Performance is excellent with 20WRMS per channel at 14.4V into 4 ohms and THD of less than 0.03%. Shortform kit only.



- Kit includes PCB & on-board electronic components
- 12VDC
- Recommended heatsink: Use HH-8570 $4.50

Clifford The Cricket

KC-5178 $12.50 plus postage & packing



Clifford hides in the dark and chirps annoyingly until a light is turned on - just like a real cricket. Clifford is created on a small PCB, measuring just 40 x 35mm and has cute little LED insect eyes that flash as it sings. Just like a real cricket, it waits a few seconds after darkness until it begins chirping, and stops instantly when a light comes back on.

- PCB, piezo buzzer, LDR plus all electronic components supplied

AUDIO AMPLIFIER KITS

"The Champ" Audio Amplifier

KC-5152 $6.00 plus postage & packing

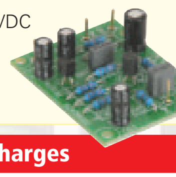
This tiny module uses the LM386 audio IC, and will deliver 0.5W into 8ohms from a 9V supply making it ideal for all those basic audio projects. It features variable gain, will happily run from 4-12VDC and is smaller than a 9V battery, allowing it to fit into the tightest of spaces.

- PCB and all electronic components included

"Pre-Champ" Versatile Preamplifier

KC-5166 $6.50 plus postage & packing

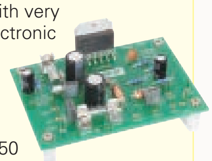
This tiny preamp was specifically designed to be used with the 'Champ' amplifier KC-5152. Unless you have a signal of sufficient amplitude the 'Champ' will not produce its maximum power output. The 'Pre-Champ' is the answer with a gain in excess of 40dB, which is more than enough for most applications. You can vary the gain by changing a resistor and there is even provision on the PCB for an electret microphone. Use AM-4010 $2.00.



- Power requirement: 6-12VDC
- Kit includes PCB and electronic components
- Can be battery powered

50 Watt Amplifier Module

KC-5150 $22.00 plus postage & packing



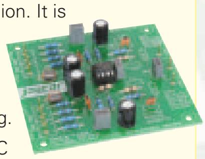
This 50 watt unit uses a single chip module and provides 50WRMS @ 8 ohms with very low distortion. PC Board and electronic components supplied. PC Board size only 84 x 58mm. Requires heatsink. See website for full specs.

- Heatsink to suit HH-8590 $12.50

Universal Stereo Preamplifier

KC-5159 $12.50 plus postage & packing

Based around the low noise LM833 dual op-amp IC, this preamp is designed for use with a magnetic cartridge, cassette deck or dynamic microphone. The performance of this design is far better than most preamps in many stereo amplifiers, making it a worthy replacement if your current preamp falls short of expectation. It features RIAA/IEC equalisation, and is supplied with all components to build either the phono, tape or microphone version. It is ideal for incorporating into existing equipment and is hence supplied short form of PCB and specified components plus PCB standoffs for mounting.

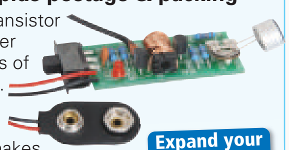


- Power requirement: +/- 15VDC
- PCB: 80x78x30mm
- If power is not available in your equipment use MM-2007 $5.50.

RADIO KITS

Miniature FM Transmitter

KE-4711 $9.75 plus postage & packing



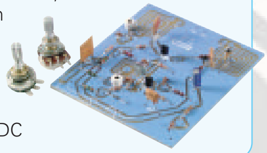
This unit is a two transistor two stage transmitter that has the benefits of being very compact. Kit contains PCB, 9V battery and all components, and makes an ideal, inexpensive beginners kit.

Expand your knowledge of radio!

- PC board size: 45 x 22mm
- 9VDC

100-200MHz VHF Converter

KG-9128 $22.00 plus postage & packing



This simple to build kit makes it feasible to receive, for example, taxis, amateur radio operators, marine radio, television audio carriers, etc. The kit connects in-line with your VHF receiver's antenna avoiding messy installation and receiver modifications.

- Operating voltage 9VDC

Post & Packing Charges

Order Value	Cost
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$50 - $99.99	$20
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$200 - $499.99	$60
$500+	$75

Max weight 550lb (250kg). Heavier parcels POA. Minimum order $25.

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FUNDAMENTALS FOR THE BEGINNER

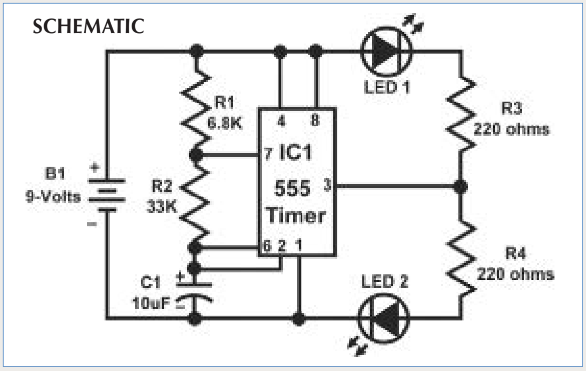
Build Railroad Lights

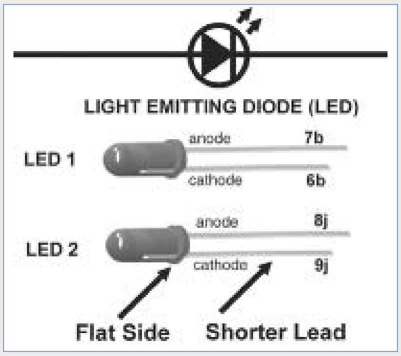
A kit for these experiments can be purchased from the *Nuts & Volts* Webstore at **www.nutsvolts.com** or call us at **800-783-4624**.

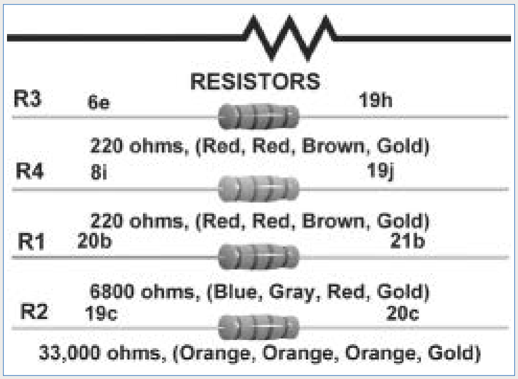
Use this month's circuit to create railroad crossing lights for your model train tracks.

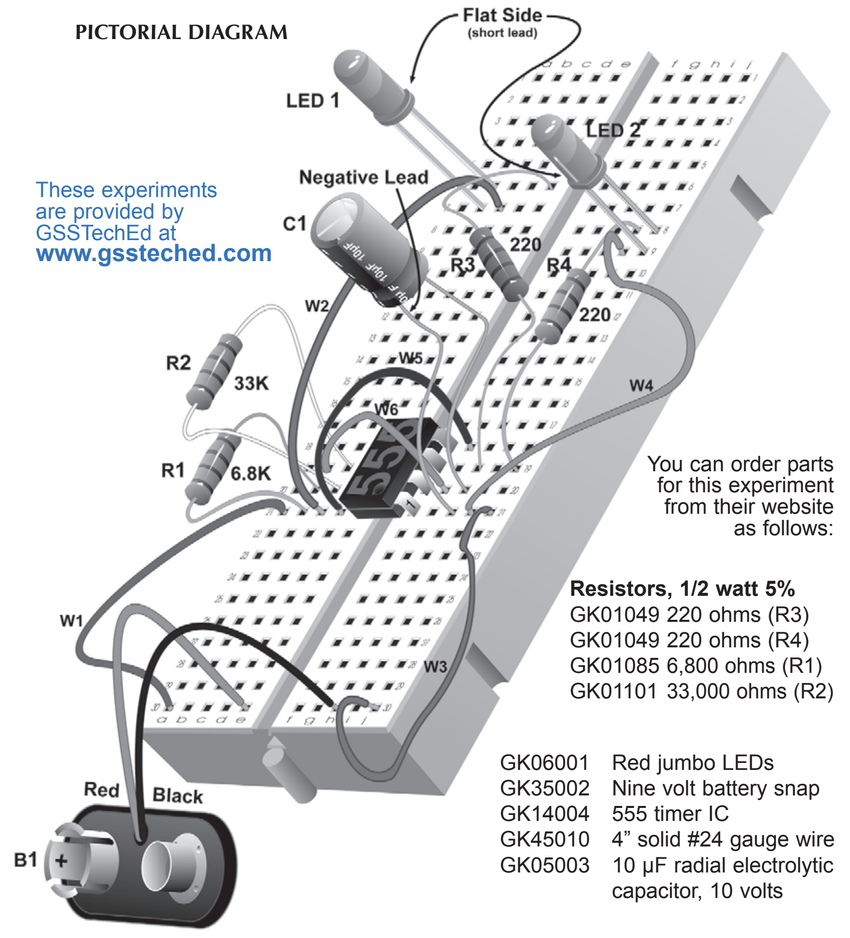
Build the Circuit. Using the schematic along with the pictorial diagram, place the components on a solderless breadboard as shown. Verify that your wiring is correct.

Do the Experiment. **Theory:** This time, we are using a 555 timer as a 'clock' with a 50% duty cycle which means that the amount of time pin 3 (of the 555 timer) is high is the same amount of time it is low. You will notice that LED 1 and LED 2 are on just about the same amount of time. The speed of 'blinking' can be adjusted by changing the values of R1, R2, and C1. However, as you change these values, you will also change the duty cycle unless you maintain a certain ratio between the values. (If you'd like more info on the formula for changing these values, refer to the Oct '10 Experiment.) **Procedure:** Connect a nine volt battery to the battery snap. You should see the LEDs lighting up one after another, just like a railroad crossing sign.


SCHEMATIC
R1
6.8K
4
8
LED 1
R3
220 ohms
B1
9-Volts
+
-
7 IC1
555
Timer
3
R2
33K
6 2 1
R4
220 ohms
C1
10uF
+
LED 2


LIGHT EMITTING DIODE (LED)
LED 1
anode
7b
cathode
6b
LED 2
anode
8j
cathode
9j
Flat Side
Shorter Lead


RESISTORS
R3
6e
19h
220 ohms, (Red, Red, Brown, Gold)
R4
8i
19j
220 ohms, (Red, Red, Brown, Gold)
R1
20b
21b
6800 ohms, (Blue, Gray, Red, Gold)
R2
19c
20c
33,000 ohms, (Orange, Orange, Orange, Gold)

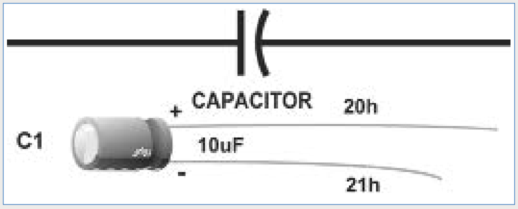

PICTORIAL DIAGRAM
Flat Side
(short lead)
LED 1
LED 2
Negative Lead
C1
220
R3
R4
220
W2
W5
R2
33K
W6
W4
R1
6.8K
W1
W3
Red
Black
B1
+
a b c d e
f g h i j

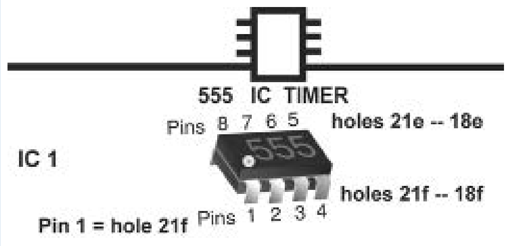
These experiments are provided by GSSTechEd at **www.gssteched.com**

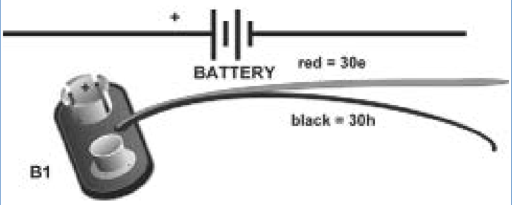
You can order parts for this experiment from their website as follows:

Resistors, 1/2 watt 5%
GK01049 220 ohms (R3)
GK01049 220 ohms (R4)
GK01085 6,800 ohms (R1)
GK01101 33,000 ohms (R2)

GK06001	Red jumbo LEDs
GK35002	Nine volt battery snap
GK14004	555 timer IC
GK45010	4" solid #24 gauge wire
GK05003	10 µF radial electrolytic capacitor, 10 volts


CAPACITOR
+
20h
C1
10uF
-
21h


555 IC TIMER
Pins 8 7 6 5
holes 21e -- 18e
IC 1
555
holes 21f -- 18f
Pin 1 = hole 21f
Pins 1 2 3 4


+
BATTERY
red = 30e
black = 30h
B1

WIRES
W1 = 21a and 30a
W2 = 7c and 21c
W3 = 21j and 30j
W4 = 9i and 21i
W5 = 18g and 21d
W6 = 20g and 19b

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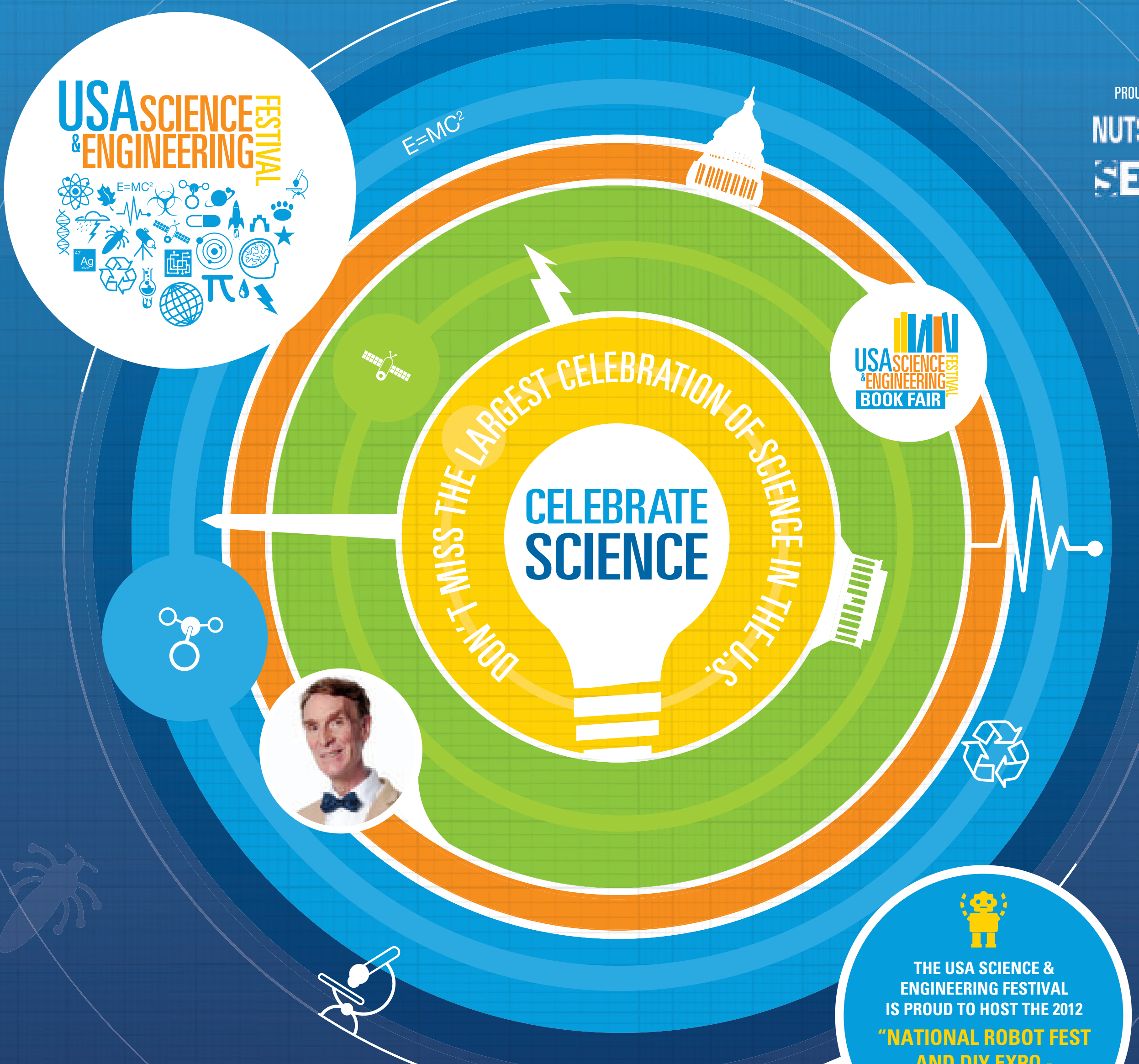
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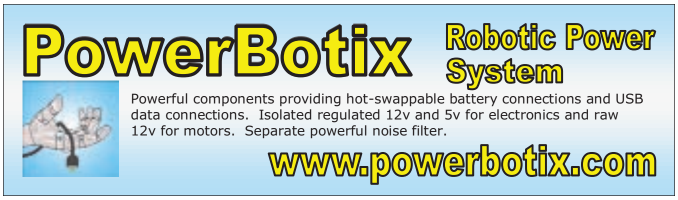
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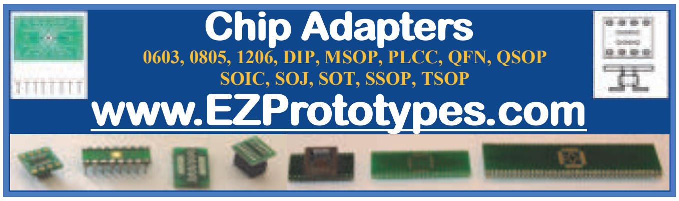
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■ BY LOUIS E. FRENZEL W5LEF

HOW TO GET YOUR HAM LICENSE

Best Hobby In The World Just Waiting For You To Join

If you are interested in electronics and radio communications, why aren't you a ham? What has been holding you back from becoming an amateur radio operator? I know. It's probably the FCC (Federal Communications Commission) exams — especially the code test. Well, in case you haven't heard, the FCC dropped the code test a few years back. You do still have to take an exam on basic communications rules and regulations, and basic electronics, but if you are reading this magazine, you may be partially qualified already. It just may be time for you to rethink the whole ham radio opportunity.

FIVE GOOD REASONS TO BECOME A HAM

You are probably asking "What's in it for me?" I can still enjoy radio and electronics without a ham license. Up to a point you can. With a license, you have so many more opportunities. In any case, here are a few good benefits to consider:

1. No code test. While you can still operate continuous wave (CW) with Morse code, you don't have to. So, you don't have to go through the training and practice to learn the code and become proficient as you used to. Code was easy for some of us who still prefer that mode of communications. Yet, CW was a real ordeal for many. Well, forget about it. It was a barrier that is no longer there.

2. It is a great hobby. There are so many facets to it, you will never get bored. (See the **sidebar** on *10 Things You Can Do As a Ham.*) You can make radio contacts with millions of other hams around the US and the world. As a short wave listener, you can receive the conversations only, but as a ham you can also transmit. Since you are adding radio signals to the ether, you need the license to be sure you are on the right frequency with the correct radio mode and technology.

3. Prestige. There is a certain amount of prestige in having a ham license. Those call letters you are assigned come only after you prove to the FCC that you have a certain amount of basic knowledge about radio operating procedures, rules and regulations, and electronic fundamentals. The exams are not easy, but they are within reach of anyone who can read and understand basic ideas. It is a real ego boost to get that license and call sign in the mail.

4. Learning experience. Like most hobbies, ham radio is a learning experience. You need to do some learning to pass the exams, but after that as you continue to experiment with radio you will keep on learning new stuff. Learning is actually fun. It is what humans do on a regular basis. Ham radio just focuses your learning and puts you on the path to a greater depth of knowledge regarding radio and electronics.

5. Social networking. Social networking like Facebook, Twitter, Google+, LinkedIn, and others are so yesterday. They are a recent *but not a new* phenomenon. Hams have been practicing social networking for decades over the air, and at their local club meetings and hamfests. The neat thing about this kind of social networking is that all the participants share the same interests.

LICENSE OPTIONS

The FCC currently offers three primary license options. These are the Technician Class, General Class, and Extra Class. Each of the three classes has different operating privileges based on the degree of technical knowledge you need to know to pass the exams. The simplest and entry level class is Technician. Here is a snapshot of the basic privilege of each class:

Technician Class

Your privileges are mostly voice operation in the six, two meter, and 70 cm (VHF and UHF) bands which is where you'll want to be to do local contacts through repeaters. You can also use the 902 and 1,240 MHz bands with any mode of operation.

In addition, some of the lower bands such as 80, 40, 15, and 10 meters are available using CW only, or CW and digital — as well as a little bit of voice — on 10 meters.

General Class

You keep all the Technician privileges, plus gain partial use on all of the lower (high frequency) bands for voice and CW/data. Some small segments of the HF bands are restricted to the Extra class licencees.

Extra Class

This is the ultimate prestige license. Extra Class gives you unrestricted use of all of the bands or modes of operation available to hams.

EXAMS

You must begin by getting your Technician Class license. It is fast and easy to get. Then when you get some experience, you can study up for the General Class, and then the Extra Class. You must take the exams in that order.

Each class of license has its own exams. These are divided into sections called Elements. The Technician Class requires the Element 2 exam which covers essential rules and regulations, operating procedures, and some basic electronics and radio fundamentals emphasizing VHF and UHF band operation. The exam has 35 questions and you need to answer 26 or more to pass (74%).

The General class exam is Element 3. Element 3 has more technical material on electronic circuits and radio fundamentals, plus details on high frequency (HF) operation. It also has 35 questions, and you need a passing grade of 74% or more.

The Extra Class exam is Element 4. Element 4 is a fairly technical exam on electronic theory and advanced ham radio operating practice. More advanced knowledge of operating modes and equipment is needed to pass this challenging exam. However, if I could pass it as I did a while back, you can too.

The exam has 50 questions and you need a passing grade of 74% (37 or more correct).

HOW TO GET THE LICENSE

Here is a step-by-step process you can follow:

1. Go to the FCC website and read about the Amateur Radio Services and ham licenses (**http://wireless.fcc.gov/services/index.htm?job=service_home&id=amateur).** Get familiar with the FCC website. It is a real handful, but has lots of good info. Practice navigating the site.

2. Get yourself some reference and learning materials to study for the exams. There are multiple sources for this.

One source is The W5YI Group which sells the Gordon West WB6NOA materials. See their books and study guides at **www.w5yi.org**.

The amateur radio professional society called the American Radio Relay League (ARRL) has been publishing license study manuals for decades. Their license manuals

10 THINGS YOU CAN DO AS A HAM

1. Voice communications. This will most likely be your number one communications mode. It is for most hams. On the lower high frequency (3 to 30 MHz) bands, you will use single sideband (SSB) — a type of amplitude modulation. On the VHF and UHF bands, you will use frequency modulation (FM) with handheld radios via repeaters. The conversations are casual and fun. It's called "rag chewing."

2. Video. Yes, you can actually do television with ham radio. It is not as widespread as voice or CW, but it can be done. And it is a great technical challenge and experience.

3. Go digital. If you don't want voice or CW, try digital. This mode of communications uses digital modulation modes to communicate by computer. You type your communications on a PC or laptop keyboard and get the return conversation on your screen. Totally cool.

4. Satellites. I'm not kidding. Hams actually have their own satellites. They act as radio relay stations in the sky so you can communicate with hams around the world. Quite an experience and technical challenge.

5. Contests. If you get bored with just casual conversations, you can always try contesting. If you like competition, you can get involved in the many contests that let you work as many stations as possible on a certain band at a certain time, or at some special occasion.

6. DX. DX means distance and refers to working foreign countries. There are hundreds to choose from and the goal is to work as many as you can. It is harder to do than making US contacts and is also competitive, but doable.

7. Field day. This is a day (or more) set aside in the summer where the goal is to take your station into the field and work as many stations as possible. The challenge of it is to work on a mountain, at the beach, or in the woods or other outdoorsy place. The fun is portable power, jury rigged antennas, and card table operating positions. Mosquitoes, bears, snakes, tents, and all the usual camping fun is part of it. Not for everyone, of course.

8. Teaching others. Become a ham license trainer for high schools, scout groups, or in your club to get new members.

9. Experimentation. This is a wide open area that lets you try out all sorts of electronic things. Antennas are a big fascination for many. You can also build all your own transmitters, receivers, etc. There are endless accessories to build and play with.

10. Work CW (Morse Code). If you like the code and don't mind learning it, this is a great option in communications. Many hams like and prefer it. It takes a bit of patience to learn and master, but after that most get hooked. Try it.

are available for all the license classes. Check out their website at **www.arrl.org**. You may want to consider joining ARRL and getting their famous magazine *QST*. If you are going to join this hobby, ARRL and *QST* should be a part of it.

There are also multiple small publishers that put out practice exams you can buy and use to check your readiness. Look in the latest issues of *QST* or *CQ* for some of these.

Finally, you can get examples of exam questions from the FCC. You can find them on the website. An easier source is the ARRL's site (**www.arrl.org/question-pools**). These are huge Word or pdf files that run many pages. If you are willing to print them out, they are free. There is a set of pool questions for each exam class. If you study these questions and can answer them, you can nail the exam. While you are downloading pool questions, download the FCC's rules and regulations for amateur radio called Part 97 of the Code of Federal Regulations (CFR) Title 47. It will also serve as a study guide for the exams.

4. Take the exam. The FCC does not give you the exam directly. You take the exam from a volunteer examiner who is commissioned by the FCC for this purpose Volunteer Examiner Coordinators (VECs). There are about a dozen around the US. Go to the FCC website to get a current list. The fee for an amateur radio exam is around $14, and the VEC organizations have test teams all over the country so it is easy to find an exam session near your home.

5. After you sign up with your chosen VEC, take the exam. If you pass, you will receive your license in the mail in a few weeks. A call sign will be assigned based on what is available and your class of license. For the higher class licenses, you can also get a so-called "vanity call." A vanity call is one you choose, if it is available. Most hams choose initials or some other personal letter combination that has some relevance to them. That does cost extra. Last time I looked, it was around $14.

EQUIPMENT

You may already be thinking about this. What radio do you buy? There are a mass of choices. The best approach is to check out the ads in the ham magazines for options. If you have a ham store in your local area, go visit and check out the choices available. There are too many to discuss here. Just be sure to get something that fits your class of license but that also can be upgraded to a higher level license. For Technician, a mobile VHF/UHF radio for two meters and 70 cm (420-450 MHz) is a good choice. Don't forget a good antenna. Many handhelds are also available at a reasonable cost. I hope you'll consider getting involved with amateur radio and hamming it up with us. **NV**

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TECHNICIAN CLASS

Technician Class book
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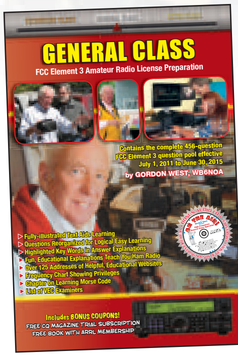
Gordo's book with W5YI software allows you to study at your computer and take practice exams. Explanations from Gordo's book are on the software – answer a question wrong and his explanation appears to reinforce your learning. Includes free Part 97 Rule Book. **NCS $29.95**

Tech Audio Course on CD
Welcome to Gordo's classroom! Technician audio theory course recorded by Gordo talks you through the Element 2 question pool. Follows the order of his ***Technician Class*** book, and is full of the sounds of ham radio operating excitement! An excellent study aid if you spend a lot of time in your car or pick-up! On 4 audio CDs. **GWTW $29.95**

GENERAL CLASS

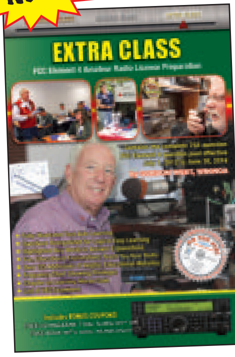


***General Class* book**
Upgrade to the HF bands with Gordo & W5YI! Gordo's manual for 2011-2015 reorganizes all the questions into logical topic groups for easier learning. His explanations include highlighted key words to help you remember the material for test success. Companion CD is full of great operating tips! Available about May 1st. **GWGM $24.95**

General Book & Software Package
Study at your computer and take practice exams. Software includes explanations from Gordo's book, scores your results and highlights areas that need further study. Includes free Part 97 Rule Book. **GUS $34.95**

General Audio Course on CD
General Theory Course recorded by Gordo is full of the sounds that bring ham radio to life! He talks you through the Element 3 theory to help you understand the material and get you ready for your upcoming exam. On 4 audio CDs. **GWGW $29.95**

NEW! EXTRA CLASS



***Extra Class* book**
Go to the top with Gordo! 2012-2016 book includes all Element 4 Q&A reorganized into logical topic groups. Gordo's fun, educational explanations with highlighted keywords, and great memory tricks for those tough theory questions! Wait 'til you meet "Eli the Ice Man!" **GWEM $24.95**

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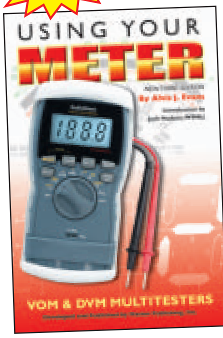
Extra Class Theory Course recorded by Gordo talks you through the difficult Element 4 theory to help you understand the material and get you ready for your upgrade to the top. On 6 audio CDs. **GWEW $39.95**

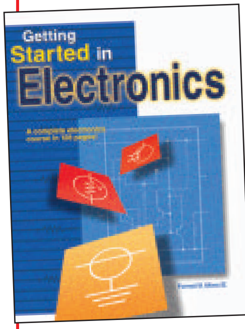
NEW! Using Your Meter



Teach yourself the correct use of your multitester. Book explains fundamental concepts of electricity including conventional and electron current and series and parallel circuits. It teaches how analog and digital meters work and tells you what the voltage, current and, resistance measurements mean. Then it provides fully-illustrated, step-by-step instruction on using your meter in practical applications in the home, workshop, automotive and other settings. An excellent learning tool and reference for the hobbyist and ham. **METR $24.95**

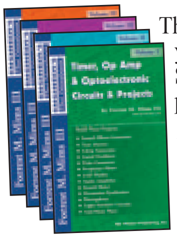
Let Forrest Mimms Teach You Electronics!

Getting Started in Electronics



This is a complete electronics course in 128 pages! This famous electronics inventor teaches you the basics, takes you on a tour of analog and digital components, explains how they work, and shows how they are combined for various applications. Includes circuit assembly tips and 100 electronic circuits you can build and test. Forrest has written dozens of books, hundreds of articles, invented scientific devices and travelled to the Amazon for NASA, and loves to share his knowledge with eager students! **GSTD $19.95**

Engineer's Mini Notebooks



These Mims classics teach you hands-on electronics! Study and build 100s of practical circuits and fun projects. Each volume contains several of his famous Mini Notebooks. Terrific ideas for science fair projects and a great way to learn about electronics! Useful reference guides for your workbench!

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NEW!

by Thomas Willeford

A Maker's Guide to Creating Modern Artifacts

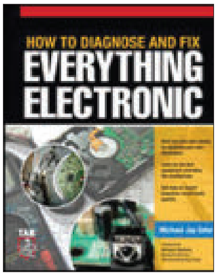
Welcome to the wondrous world of Thomas Willeford (a.k.a., Lord Archibald "Feathers" Featherstone) in which he shares his closely guarded secrets of Steampunkery. Filled with do-it-yourself projects, *Steampunk Gear, Gadgets, and Gizmos: A Maker's Guide to Creating Modern Artifacts* shows you how to build exquisite, ingenious contraptions on a budget.

$24.95

How to Diagnose and Fix Everything Electronic

by Michael Jay Geier

Master the Art of Electronics Repair!



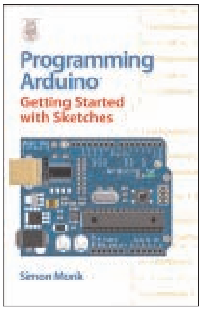
In this hands-on guide, a lifelong electronics repair guru shares his tested techniques and invaluable insights. *How to Diagnose and Fix Everything Electronic* shows you how to repair and extend the life of all kinds of solid-state devices, from modern digital gadgetry to cherished analog products of yesteryear. **About the Author:** Michael Jay Geier began operating a neighborhood electronics repair service at age eight that was profiled in *The Miami News*.

$24.95

Programming Arduino Getting Started with Sketches

by Simon Monk

Program Arduino with ease!

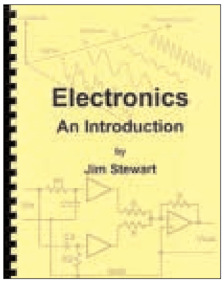


Using clear, easy-to-follow examples, *Programming Arduino: Getting Started with Sketches* reveals the software side of Arduino and explains how to write well-crafted sketches using the modified C language of Arduino. No prior programming experience is required! The downloadable sample programs featured in the book can be used as-is or modified to suit your purposes.

$14.95

Electronics An Introduction

by Jim Stewart



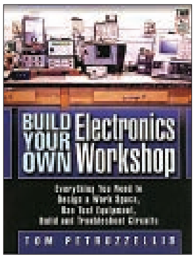
This book is designed as an in-depth introduction to important concepts in electronics. While electronics can be highly mathematical, this text is not about calculations. It is about how electronic equipment is able to extract, process, and present information held in electrical signals. If you are in — or studying to be in — a profession that requires the use of electronic equipment, then this book will provide the insight necessary to use such equipment effectively.

$33.95*

Build Your Own Electronics Workshop

by Thomas Petruzzellis

BUILD YOUR OWN DREAM ELECTRONICS LAB!



This value-packed resource provides everything needed to put together a fully functioning home electronics workshop! From finding space to stocking it with components to putting the shop into action — building, testing, and troubleshooting systems. This great book has it all! And the best part is, it shows you how to build many pieces of equipment yourself and save money, big time!

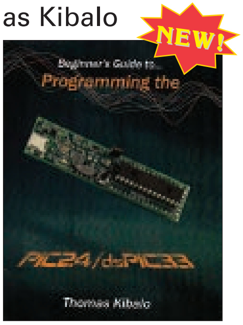
Reg Price $29.95

Sale Price $26.95

Beginner's Guide to ... Programming the PIC24/dsPIC33

by Thomas Kibalo

NEW!

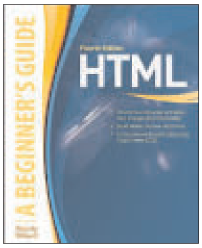


Kibalo takes you step by step through the fundamentals of programming the PIC24H which can equally be applied to the dsPIC33. His clear explanation of the inner workings make learning the PIC24H/dsPIC33 16-bit architecture easy. His code examples demonstrate how to perform the functions most applications require. The hardware is shown in a simple breadboard setup so even a beginner can build it, along with very few extra components needed.

$39.95*

HTML: A Beginner's Guide

by Wendy Willard

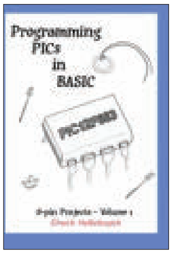


Create highly functional, impressive websites in no time. Fully updated and revised, *HTML: A Beginner's Guide*, Fourth Edition explains how to structure a page, place images, format text, create links, add color, work with multimedia, and use forms. You'll also go beyond the basics and learn how to save your own web graphics, use Cascading Style Sheets (CSS), create dynamic web content with basic JavaScript, and upload your site to the web. By the end of the book, you'll be able to build custom websites using the latest HTML techniques.

$29.95

Programming PICs in Basic

by Chuck Hellebuyck



If you wanted to learn how to program microcontrollers, then you've found the right book! Microchip PIC microcontrollers are being designed into electronics throughout the world and none is more popular than the eight-pin version. Now the home hobbyist can create projects with these little microcontrollers using a low cost development tool called the CHIPAXE system and the Basic software language. Chuck Hellebuyck introduces how to use this development setup to build useful projects with an eight-pin PIC12F683 microcontroller. **$14.95**

Master and Command C for PIC MCUs

by Fred Eady

Master and Command C for PIC MCU, Volume 1 aims to help readers get the most out of the Custom Computer Services C compiler for PIC microcontrollers. The author describes some basic compiler operations that will help programmers particularly those new to the craft create solid code that lends itself to easy debugging and testing. As Eady notes in his preface, a single built-in CCS compiler call (output_bit) can serve as a basic aid to let programmers know about the "health" of their PIC code.

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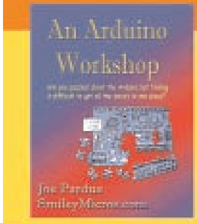
An Arduino Workshop
Joe Pardue
SmileyMicros.com

Book: An Arduino Workshop $44.95
Projects Kit $84.95

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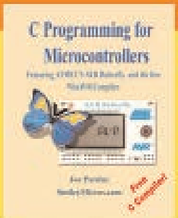
C Programming for Microcontrollers
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SmileyMicros.com
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Projects Kit $58.49

Book and Kit Combo
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Parts Kit for Smiley's Workshop

Breadboard friendly LCD and five-button keypad parts kit.

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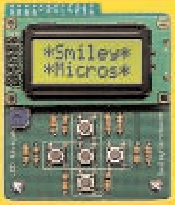
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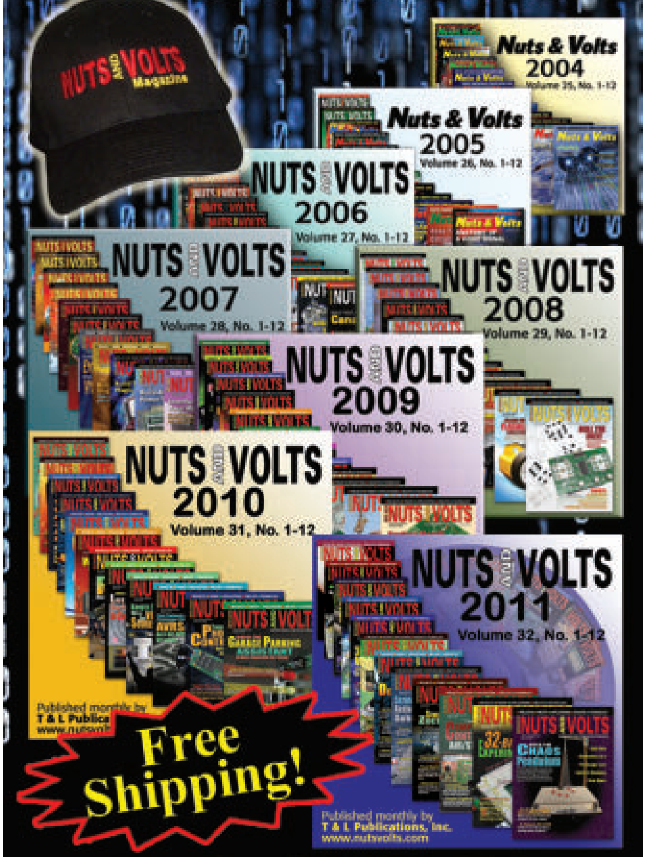
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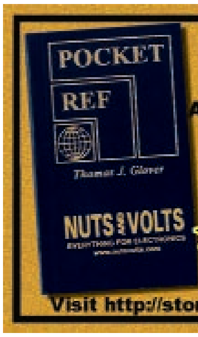
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PROJECTS

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Sale!
No Intergrated Circuits

If you like electronic puzzles, then this kit is for you! There are no integrated circuits; all functionality is achieved using discrete transistor-diode logic. The PCB is 10"x11" and harbors more than 1,250 components! For more info, see the November 2009 issue.

Reg $225.95

Sale Price $199.95

PCBs can be bought separately.

Battery Marvel Kit

MARVEL
BATTERY

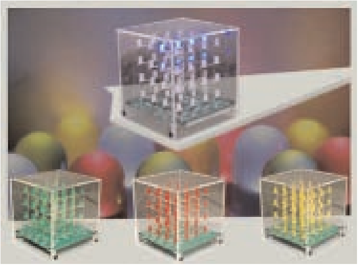
As seen in the November 2011 issue. Battery Marvel helps protect cars, trucks, motorcycles, boats, and any other 12V vehicles from sudden battery failure. This easy-to-build kit features a single LED that glows green, yellow, or red, indicating battery health at a glance. An extra-loud piezo driver alerts you to any problems.

For more info, please visit our website.

Subscriber's Price **$18.95**

Non-Subscriber's Price **$19.95**

3D LED Cube Kit

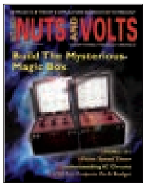


This kit shows you how to build a really cool 3D cube with a 4 x 4 x 4 monochromatic LED matrix which has a total of 64 LEDs. The preprogrammed microcontroller that includes 29 patterns that will automatically play with a runtime of approximately 6-1/2 minutes.
Colors available: Green, Red, Yellow & Blue

Subscriber's Price **$57.95**

Non-Subscriber's Price **$59.95**

Magic Box Kit



As seen on the April 2007 cover.

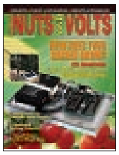
This unique DIY construction project blends electronics technology with carefully planned handcraftsmanship. This clever trick has the observer remove one of six pawns while you are out of the room and upon re-entering you indicate the missing pawn without ever opening the box.

Includes an article reprint.

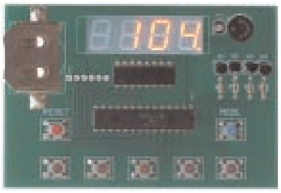
Subscriber's Price **$39.95**

Non-Subscriber's Price **$45.95**

Sorting Counter Kit



As seen in the July 2011 issue.



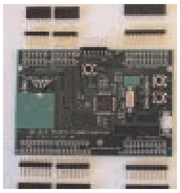
Sorting counters have many uses — keeping score, counting parts, counting people — it is just a handy gadget to have around. This is a very simple project for those who want to learn to solder or are interested in using microprocessors and how they function. No special tools are needed, just a small tip soldering iron. It has no box as it stands alone, therefore there is no drilling.

Subscriber's Price **$33.95**

Non-Subscriber's Price **$39.95**

32-Bit Micro Experimenter Board

The 32-Bit Micro Experimenter is the fastest way to learn 32-bit microcontrollers.



The kit includes onboard 46 programmable I/O and USB, free software, carefully documented step-by-step experiments for USB, embedded web server, graphics and audio, wireless, RTOS, and file I/O. User pushbuttons, LEDs, and 32 kHz clock crystal. Can be used in solderless breadboard environment or stand-alone.

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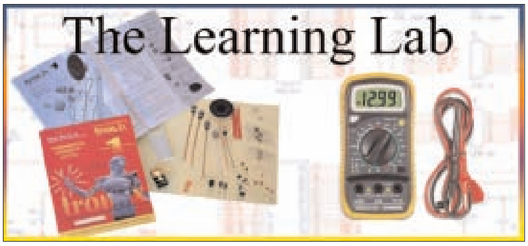

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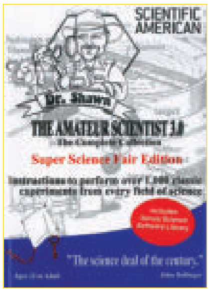
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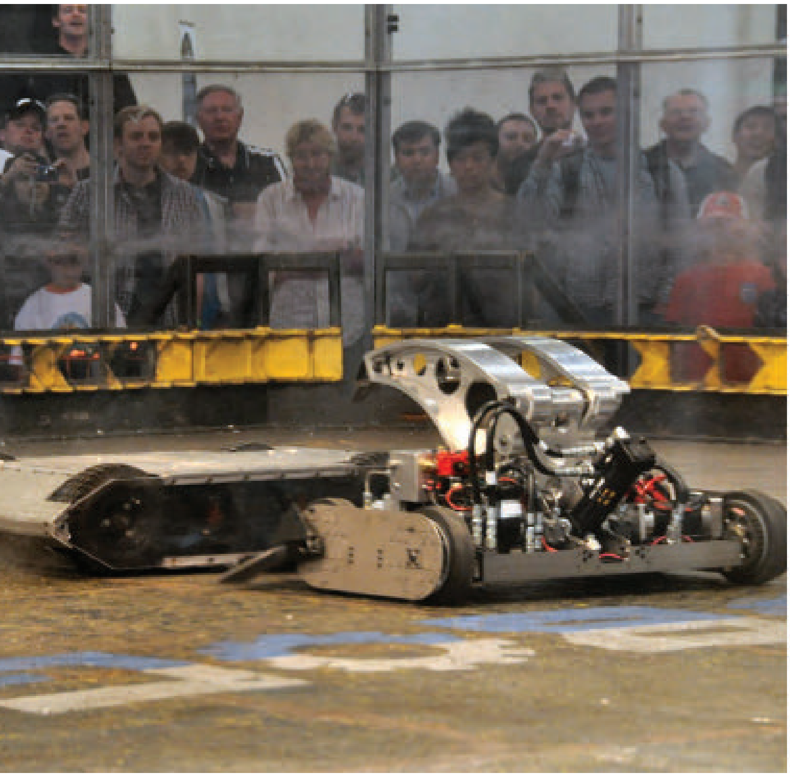

MASTER – DISASTER
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RoboGames is the olympics for robots – a three-day event in the San Francisco Bay Area that brings the smartest humans and best robots from around the world to compete in a wide array of robotics oriented events (over 40 countries have participated in past events.)

Cart-wheeling androids, combat robots, autonomous vehicles, LEGO robots, soccer bots and even cocktail-mixing barbots – there’s something for everyone at RoboGames! The event also features demonstrations by leading robotics industry designers and engineers, kinetic art exhibits, and the latest in tech products, gear, and innovation.

RoboGames began as an enthusiastic experiment in robotic cross-pollination, when dozens of disparate, well-established robot competitors were placed under the same roof. Bringing together builders from acclaimed fields such as combat robotics, robot soccer, sumo, fire-fighting, androids, and kinetic art, RoboGames enables robot builders to exchange ideas and share their knowledge and experience with each other. Varying disciplines now learn from one-another and the event has grown into a fantastic multi-layered, multi-cultural experience like no other. The best part is that RoboGames is completely open–anyone can compete: competitors have been garage builders, K-12 school teams, professional engineers, and university researchers. Come see the future evolve!

Educational Outreach: In addition to the 60 adult events, RoboGames sponsors 10 different “junior league” events for kids in K-12, which are free for kids to compete. University students also have the opportunity to publish and present research papers.

Sponsors: Your company can reach millions of people around the world by sponsoring RoboGames. Tens of thousands of people attend the event in person, and millions are reached from the media-exposure – print, web, radio, and television. Popular with techies, sports-fans and hipsters alike, RoboGames has something to offer every demographic.

Go on-line to find out more! Watch videos, get building tips, register to compete, buy tickets or sponsor the next event.

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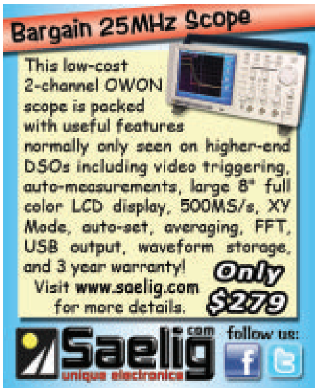
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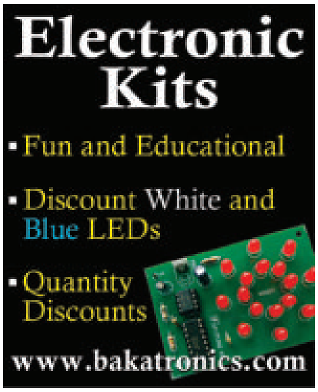
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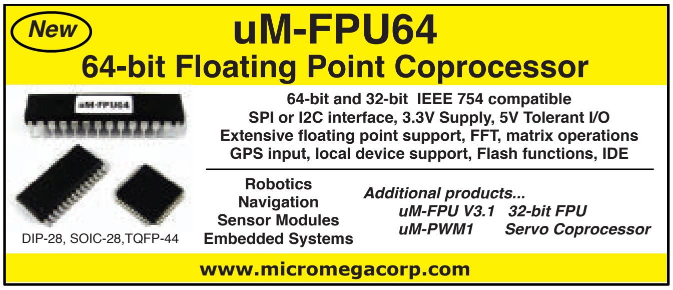
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with easy-to-use outputs and the standard pin configuration of previous MaxSonar products. In addition to the three standard sensor outputs of RS-232 serial, analog voltage, and pulse width there is now a user selectable TTL serial output. The final assembly is a small unit less than one cubic inch; it weighs 4.3 grams and operates from 3V to 5V. The HRLV-MaxSonar-EZ is available for $34.95.

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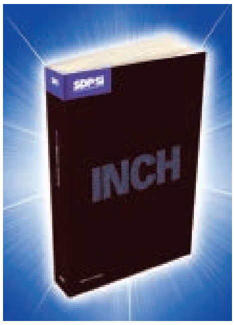

NEW CATALOG FROM SDP/SI

Stock Drive Products/Sterling Instrument has just put out their new D810 Inch Catalog — it's a completely easy-to-use book that includes new products, detailed indexes, and comprehensive technical data. It features over 87,000 components including an entirely new section of industrial quality leveling foot mounts.

Since the first all inch master catalog was released, SDP/SI has revised and expanded the existing product groups while introducing thousands of new drive components such as timing belts, pulleys, timing belt clamps, clamp kits, Fairloc®, foot mounts, bearings, gearheads, couplings, vibration mounts, and much more.

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>>> QUESTIONS

Half Cycle Magnetizer

I would like to find a schematic for a half cycle magnetizer. The one that I have runs on three phases but I need one that runs off of the 120 volt line at 60 cycles. The working load that I need is about 5" x 5" x 4" or bigger. The specs for the output coil and the fast solid-state switch are most important. I realize that the magnetizer must be enclosed with non-magnetic material and probably uses a big heatsink.

#4121 **Bob Macias**
Fernandina Beach, FL

Transformer

How do I calculate the number of turns for both the primary and the secondary windings of a transformer?

#4122 **Opeyemi**
Ibadan, Oyo

Phone Text Book

I am an electrical technician looking for a textbook or reference that deals with landline phones. I am wanting to learn the info that a phone technician would use such as multi-phone land lines, troubleshooting phone lines, and the definitions that are used in the industry.

Please direct me to a text book that would be a useful resource of learning and a good reference for down the road.

#4123 **Jim Houser**
Cambridge, OH

>>> ANSWERS

### [#2123 - February 2012]
Tools

I'm just getting started in electronics and need advice on what kinds of tools I should get to make my projects easier.

Start with a soldering kit (such as RadioShack's Cat. No. 64-2803), plus a couple of rolls of solder removal braid and a roll of rosin core solder (the RoHS stuff is "greener" but it's a pain even for seasoned veterans). If you plan to remove a lot of components from scrapped boards, a vacuum desoldering tool will keep your hair on your head. I learned to solder at eight years old (52 years ago) with my grandfather's 250 watt soldering gun and a roll of solder that looked like it could be used to solder pipes, so the low wattage soldering irons used today are a snap. At 10 years old, my grandfather gave me a guitar amp. I learned not to troubleshoot the black tubes by touching them to see if they were warm (fried a finger tip in the process). **CAUTION: Wear safety goggles or glasses when soldering and don't even think about surface-mount devices yet.** Practice soldering by attaching two small wires together and then move up to a kit. Ramsey Electronics (**www.ramseykits.com**) has a lot of neat electronics kits for both beginners and old pros. Later, you will build some of your own designs or those from the authors of *Nuts & Volts*, and will need components; Jameco (**www.jameco.com**), Mouser (**www.mouser.com**), and Digi-Key (**www.digikey.com**) are good sources. Don't worry about microcontrollers now, but later you may try them and catch the programming bug. Good luck, keep trying new things, and don't give up. Before you know it, you'll be an old pro too.

Tim Brown
Honea Path, SC

### [#2125 - February 2012]
Home Intercom System

I would like to put together an intercom system for my house. I want to be able to connect multiple stations, perhaps up to 10 or 12. I'd like to use twisted pair wiring, not shielded wire (for example, existing two pair telephone or four pair CAT 5). I would like to use a central power supply rather than individual batteries or power supplies. I don't need hands-free operation, so a simple push to talk function would be fine, and I'm not concerned about privacy, so when one station is talking, all stations would hear the conversation.

I've seen some two station circuits using LM386 but I can find nothing about creating a multi-station system.

#1 Think wireless!!! Go to **gadgetshack.com** and look at the Westinghouse two-channel basic home intercom system. For $59 per pair of units and a reputed "unlimited number" of units that can be used with full security, this is a lot cheaper and less of a "pain" than running cable. Running cable in an existing house is very difficult and installing cable in a new house is still expensive.

Tim Brown
Honea Path, SC

#2 The intercom system desired is very similar to the headset intercoms used to communicate with camera operators and other studio personnel in every TV station and network for many years now. Although there are variations and expansions, the basis of these systems is a two-wire party line that carries both the conversation and the power (24 to 48 volts DC) to run the various stations so that no separate power connection is needed.

All questions *AND* answers are submitted by *Nuts & Volts* readers and are intended to promote the exchange of ideas and provide assistance for solving technical problems. Questions are subject to editing and will be published on a space available basis if deemed suitable by the publisher. Answers are submitted by readers and **NO GUARANTEES WHATSOEVER** are made by the publisher. The implementation of any answer printed in this column may require varying degrees of technical experience and should only be attempted by qualified individuals.

Always use common sense and good judgment!

They are probably similar to the two-station intercom circuits you have seen and many of these can be adopted for this use with the additional components shown in **Figure 1**. The basic idea is that each station must separate the audio and power components that are sent over the same two wires. Also, the audio must be blocked from entering the output terminals of the DC power supply because the filter capacitors in it will have a very low AC impedance and would short the audio to ground. There were also party line systems that used a four-wire connection to keep these two components separate, but I will ignore them here because a two-wire system was requested.

One wire is a signal and power ground, while the other carries both the audio and power. The basic audio circuit is simply an amplifier connected to the two-wire party line through a simple two-pole momentary switch which allows only one of these functions to occur at a time, thus preventing any feedback. I have shown a DPDT in the **schematic** to allow the speaker to be used as a microphone, but a separate mic could be used with a SPDT switch.

The coil labeled L1 is necessary to present a high impedance to audio frequencies on the party line which would be shorted by the filter capacitors in the power supply. It needs to have a fairly high inductance value in order to preserve the lower audio frequencies. You need whole Henries here, not milli or micro Henries. The formula for the impedance is 2*Pi*F*L and you want an inductive impedance value in thousands of ohms at about 100 Hz or lower. At 100 Hz for a 10 Henry (H) inductor: 2*3.141*100Hz*10H = 6283 ohms. This should work. It should be rated for the combined current of all the stations. The largest inductor I could find with a quick search is a 15 H coil but it was shown as "out of stock" with a delivery time of over 100 days. There are some being offered on eBay; search for "retard coil" and you will get what you need, but they are not cheap. There are high inductance chip-style inductors but I doubt they would work because they would not pass the DC current needed to operate all the stations.

In the stations, the capacitor labeled C1 blocks the DC voltage to the audio amplifier. It must have a

R9
U22
C32
C23
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R11
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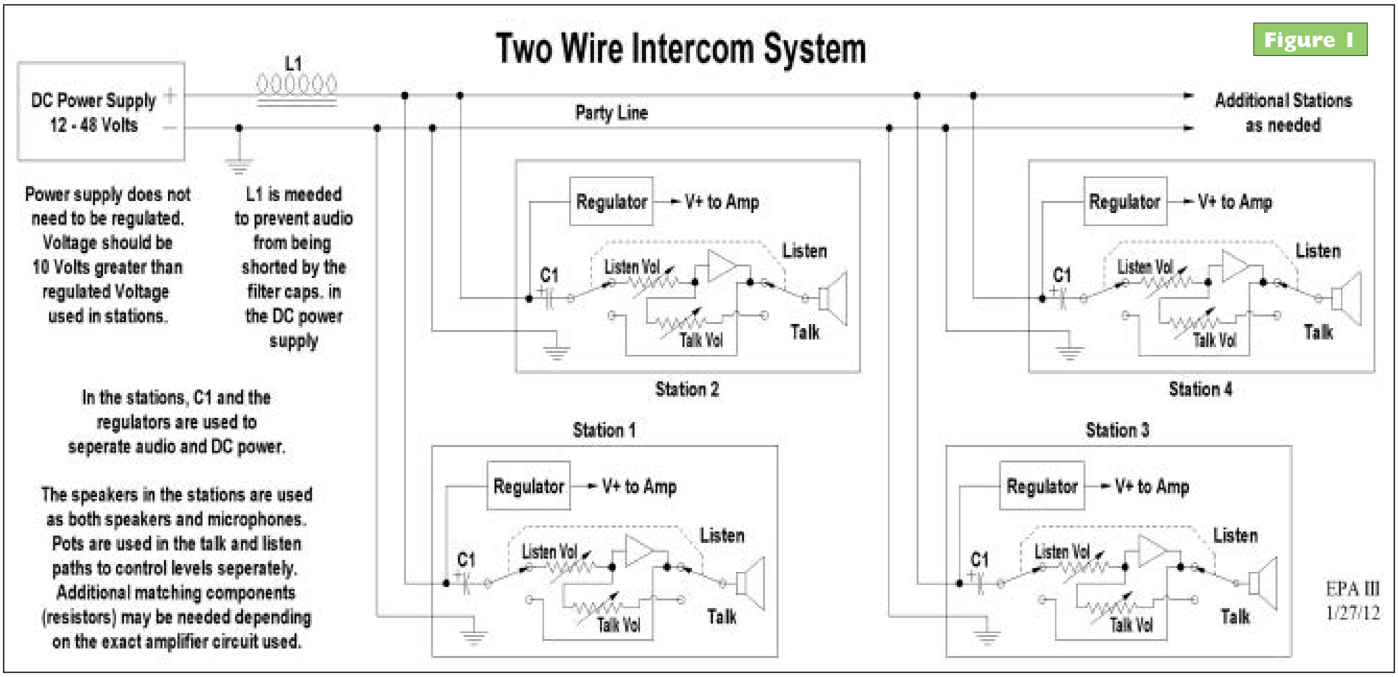

Figure 1

Power supply does not need to be regulated. Voltage should be 10 Volts greater than regulated Voltage used in stations.

L1 is meeded to prevent audio from being shorted by the filter caps. in the DC power supply

In the stations, C1 and the regulators are used to seperate audio and DC power.

The speakers in the stations are used as both speakers and microphones. Pots are used in the talk and listen paths to control levels seperately. Additional matching components (resistors) may be needed depending on the exact amplifier circuit used.

voltage rating that is higher than the power supply output voltage and a low capacitive reactance in relation to the amplifier's input impedance. The formula for the capacitive reactance is 1/(2*3.141*F*C). If the amplifier you use has an input impedance of 10K ohms and you have 10 intercom stations, the combined parallel impedance on the party line will be 1,000 ohms; you will want a capacitive reactance of 100 ohms or less. Again, we calculate at the lowest desired frequency or about 100 Hz. A 15 µF capacitor will give us 106 ohms of capacitive reactance at 100 Hz and should work. I would probably step up to 25 µF or even 50 µf as the added cost will be tolerable and the low frequency performance will be improved.

Any of a number of solid-state or IC audio amplifier circuits could be used. Look for a high input impedance and a low output impedance suitable for driving your speaker. The gain needed will depend on the output level of the microphone or of the speaker when used as a mic and the desired line level on the party line. Since you want to use unshielded wire, I would suggest a line level of about +10 dBm or about three volts RMS in order to keep any noise to a minimum. Assuming the microphone level is -40 dBm, you would need a +50 dBm gain in the amplifier. I would go for one that provides +60 dBm to allow the volume controls room to work. The volume controls can be simple voltage division circuits with one side of the pot connected to the input signal, the other side to ground, and the output taken from the wiper; 10K or 50K audio taper pots should work with most types of amplifiers.

Figure 1 shows the DC power supply to have an output voltage that is significantly higher than the regulated voltages in the stations. This is because there are no filter capacitors on the party line. So, the regulator circuits in the stations must have sufficient voltage to stay in regulation, even during the loudest audio which will both add to and subtract from the average DC voltage provided by the power supply. So, with a three volt RMS audio level, half of the P-P value of the audio will be about 4.5 volts. This — on top of a supply voltage of 25 volts DC — will give a total voltage which will swing from 20.5 to 29.5 volts. If the regulator needs a three volt headroom to operate, this is subtracted from the minimum value of 20.5 to give a maximum regulated voltage of 17.5 volts. An 18 volt regulator would fall out of regulation on loud audio and cause distortion in the amplifier. Thus, there is a need for an unregulated voltage that is about 10 volts higher than the output of the regulators chosen.

Finally, a word about the type of wiring you wish to use. Telephone wires and Cat 5 network wires are relatively small gauge, so the power current will be somewhat limited. If you have multiple stations on a single run of such wire, the current needed for a single station will be multiplied by the number of stations on the run. This may cause problems with excessive voltage drops. Also, longer runs will add to this problem due to increased resistance in the wiring. The systems in TV stations I referred to earlier commonly only have to power headsets — not speakers — so less power is needed. I would suggest heavier gauge wiring; common lamp cord or even doorbell wire may work better. If you must use telephone or Cat 5 wiring, they commonly have four conductors and you should consider doubling up for both the ground and the signal/power conductors.

Paul Alciatore
via email

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Programmable DC Electronic Load 0~80V / 0~40A

The 3721A Programmable DC Electronic Load provides excellent performance with sophisticated features found on much more expensive units. This 400 watt, 40 Amp, 0~80 volt Programmable DC Electric Load can be used to test all sorts of DC power sources including power supplies and is especially helpful to battery manufacturing processes. This DC load features constant voltage, constant resistance, constant current and constant power settings. The end user can design programs that control precisely all of the load values and time durations for each step of a test sequence. Up to nine 10 step programs can be internally stored in the 3721A Programmable DC Load.

4 basic functions: CC, CV, CR & CP

8 basic test modes: CCL, CCH, CV, CRL, CRM, CRH, CPV & CPC

Minimum operating voltage is less than 0.6v at the load's full rated current.

High-speed sequence, high-speed transient, short circuit, battery discharge and other functions.

Programable current slew rate.

Multiple groups of parameters and lists can be saved & recalled.

Supports SCPI and LabView with included software.

Current Rating: 0~40A

Voltage Rating: 0~80V

Power Rating: 400W at 40°C

Item#
CSI3721A **$720.00**

www.CircuitSpecialists.com/CSI3721A

Programmable DC Electronic Loads

Thease devices can be used with supplies up to 360VDC and 30A. It features a rotary selection switch and a numeric keypad used to input the maximum voltage, current and power settings. These electronic DC loads are perfect for use in laboratory environments and schools, or for testing DC power supplies or high-capacity batteries. It also features memory, and can also be connected to a PC, to implement remote control and supervision.

360V/150W (CSI3710A) $349.00
www.circuitspecialists.com/csi3710a
360V/300W (CSI3711A) $499.00
www.circuitspecialists.com/csi3711a

60 Watt Digital Soldering Stations

For use with traditional or Lead Free Soldering

Top Seller!
Circuit Specialists, Inc.
450
CSI-STATION-3DLF

The CSI-Station-3DLF is a powerful 60 watt soldering system. The fast heat recovery provided by a 60 watt system like this allows the user to solder both traditional solder and lead free solder. This system features a grounded tip to protect delicate circuits from static charge. Specific system temps can also be set with an easy to use push button up/down button AND when you turn off this station, the unit keeps the last used temperature in memory & automaticly returns to that setting the next time the user turns the system on.Also included is a seperate iron holder. Circuit Specialists stocks a large supply of tips for this station.

Features:

- 60 watt dual core ceramic heater
- 150 to 450 degree Celsius Temperature range
- 302 to 896 degree Fahrenheit Temperature range
- Versatile easy to read liquid crystal display
- 3 preset & user definable temperature settings.
- Automaticly remembers previous temperature setting
- Display in Celsius or Fahrenheit scale
- 3 foot cord length from station to iron tip
- Broad selection of replacement tips available

Item#
CSI-Station-3DLF **$49.00**

www.CircuitSpecialists.com/CSI-Station-3DLF

Pb
lead-free
NEW
Circuit Specialists

Here is another 60 Watt soldering iron at a price that can't be beat. This is the "little brother" of our overwhelmingly popular CSI-STATION-3DLF except we have removed the Digital Display & Digital controls. But at 60 watts of power, this unit heats up extremely fast and is suitable for soldering lead free solder or traditional solder containing lead. The analog control knob is calibrated in Celsius (200deg to 480 deg) & Fahrenheit (392 deg to 896 deg). A front panel led lights when the system is heating up and a front panel calibration port is also available. Circuit Specialists stocks replacement soldering handles & a large selection of tips for this model. It may be viewed in greater detail at our web site.

Features:

- 60 watt dual core ceramic heater
- 200 to 450 degree Celsius Temperature range
- 392 to 896 degree Fahrenheit Temperature range
- 3 foot cord length from station to iron tip
- Broad selection of replacement tips available

Item#
CSI-Station-60W **$37.95**

www.CircuitSpecialists.com/CSI-Station-60W

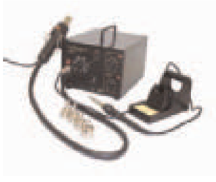
SMD Hot Air Rework Station with Suction Pick-Up Wand

What every shop or lab needs to deal with todays SMT designed circuit boards. O.E.M. manufactured just for Circuit Specialists Inc., so we can offer the best price possible! A multi-technology assembly and repair station. The heater and air control system is built-in and adjusted by the simple touch of the front keypad for precise settings. Temperature range is from 100°C to 480°C / 212°F to 896°F, and the entire unit will enter a temperature drop state after 15 minutes of non-use for safety and to eliminate excessive wear.

Item#
CSI825A **$109.00**

www.CircuitSpecialists.com/CSI825A

SMD Hot Air Rework Station with Soldering Iron

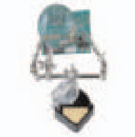


An SMT rework station & soldering station in one handy unit! Perfect for shops & labs dealing with todays SMT board designs.O.E.M. manufactured just for Circuit Specialists Inc., so we can offer the best price possible! This multi-purpose station is perfect for all your surface mount and thru-hole requirements. The soldering iron has a grounded tip for static sensitive parts and uses a ceramic heating element for fast heat up and stable temperature control. A seperate aluminum constructed soldering iron holder is included.

Item#
CSI906 **$109.00**

www.CircuitSpecialists.com/CSI906

Helping Hand with cast iron base
ZD-10F
$3.19



Magnifer, Helping Hand & Soldering Stand
ZD-10G
$4.25

56 LED Table Lamp with Glass Magnifer Lens
ZD-129LED
$39.95

Magnifying Table Lamp with 22Watt Circular Florescent Light
8066D-1C
$29.99

3.0 Diopter Magnifier with Helping Hand
ZD-10H
$7.95

Helping Hand, Magnifier with LED Light and Soldering Stand
ZD-10M
$8.99

Soldering Iron Tip Cleaner with stand
TY-88
$4.95

De-soldering pump, full sized Powerful ESD design
ZD108K
$5.99

6 Piece Solder Aid Kit (Brush, Scraper, Knife, Hook, Fork, Spike)
ZD151
$3.66

www.CircuitSpecialists.com/soldering-tools

CircuitSpecialists.com

1000's of Items Online! 1-800-528-1417 Fax: 480-464-5824 Since 1971

We carry a LARGE selection of Power Supplies, Soldering Equipment, Test Equipment, Oscilloscopes, Digital Multimeters, Electronic Components, Metal and Plastic Project Boxes, Electronic Chemicals, PC Based Digital I/O Cards, Panel Meters, Breadboards, Device Programmers, and many other interesting items. Check out our website at:

www.CircuitSpecialists.com

Best Value, Low Cost Station

CSI-Station1A

Easily our best value in our selection of soldering stations. O.E.M. manufactured just for Circuit Specialists Inc., so we can offer the best price possible! The CSI-Station1A features a grounded tip & barrel for soldering static-sensitive devices and uses a ceramic heating element for fast heat up & stable temperature control.

The control knob is calibrated in Fahrenheit & Celsius (392° to 896°F and 200° to 480°C). One of the nicest features is the high quality comfort grip soldering iron. The iron connects to the station via an easy screw-on connector making iron replacement a snap. The 1 meter length iron cord provides plenty of length for users to set up the station in a convenient location. Another nice feature is the soldering iron holder. Made of rugged aluminum,it is a seperate piece from the main station & allows the user maximum convenience.....you don't have to reach all the way back to the station to store the iron. Yet another feature is the stackable design of the CSI-Station1. The main station is designed for an additional unit to be placed on top of it allowing for space saving placement of the CSI-Station1A. Also included at no additional charge is one user replaceable ceramic heating element so that you will be prepared! Large selection of soldering tips available too.

Item#
CSI-STATION1A **$29.95**

www.circuitspecialists.com/csi-station1a

1500 Watt Hot Air Gun for heat shrink tubing

SPECIAL OFFER

Comes with FREE 154pc assortment of heat shrink tubing in a handy case.

1/16" 56 pcs
3/32" 35 pcs
1/8" 28 pcs
3/16" 18 pcs
1/4" 9 pcs
3/8" 8 pcs

An $8.95 Value!

The ZD509 is a 1500 Watt Hot Air Gun that is ideal for use with Heat Shrink Tubing or Packaging Film. Ideal for shrinking Circuit Specialists heat shrink tubing.

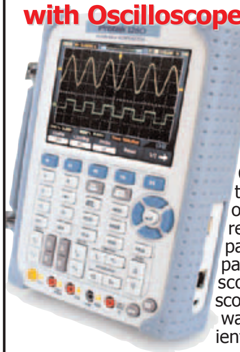
Features of the ZD509 Heat Gun:

* 1500 watts of power
* Rotating variable temperature control feature (on rear of body)
* 100 deg C- 550 deg C
* Air flow: 200-450 L/min
* CE approved
* Air flow concentrator attachment included
* Low setting provides approx 200 deg C & draws approx 800 watts
* High setting provides approx 500 deg C & draws approx 1500 watts

ZD509 $20.95

www.CircuitSpecialists.com/ZD509

200MHz Hand Held Scopemeter with Oscilloscope & DMM Functions



Includes 1 Year USA Warranty

You get both a 200 MHz Oscilloscope and a multi function digital multimeter, all in one convenient lightweight rechargeable battery powered package. This power packed package comes complete with scopemeter, test leeds, two scope probes, charger, PC software, USB cable and a convenient nylon carrying case.

- 200MHz Handheld Digital Scopemeter with integrated Digital Multimeter Support
- 200MHz Bandwidth with 2 Channels
- 500MSa/s Real-Time Sampling Rate
- 50Gsa/s Equivalent-Time Sampling Rate
- 6,000-Count DMM resolution with AC/DC at 600V/800V, 10A
- Large 5.7 inch TFT Color LCD Display
- USB Host/Device 2.0 full-speed interface connectivity
- Multi Language Support
- Battery Power Operation (Installed)

Item #
DSO1200 ***New Low Price!*** **$589.00**

www.circuitspecialists.com/DSO1200

60MHz Hand Held Scopemeter with Oscilloscope & DMM Functions

- 60MHz Handheld Digital Scopemeter with integrated Digital Multimeter Support
- 60MHz Bandwidth with 2 Channels
- 150MSa/s Real-Time Sampling Rate
- 50Gsa/s Equivalent-Time Sampling Rate
- 6,000-Count DMM resolution with AC/DC at 600V/800V, 10A
- Large 5.7 inch TFT Color LCD Display
- USB Host/Device 2.0 full-speed interface connectivity
- Multi Language Support
- Battery Power Operation (Installed)

Item #
DSO1060 ***New Low Price!*** **$429.00**

www.circuitspecialists.com/DSO1200

60MHz Hand Held Scopemeter w/Oscilloscope, DMM Functions & 25 MHz Arbitrary Waveform Generator

- All the features of the DSO1060 plus a 25 MHz Arbitrary Waveform Generator.
- Waveforms can be saved in the following formats: jpg/bmp graphic file, MS excel/word file
- Can record and save 1000 waveforms
- DC to 25 MHz Arbitrary Waveform Generator

Item #
DSO-8060 ***New Low Price!*** **$519.00**

www.circuitspecialists.com/DSO-8060

Programmable DC Power Supplies

- Up to 10 settings stored in memory
- Optional RS-232, USB, RS-485 adapters
- May be used in series or parallel modes with additional supplies.
- Low output ripple & noise
- LCD display with backlight
- High resolution at 1mV

Model	CSI3644A	CSI3645A	CSI3646A
DC Voltage	0-18V	0-36V	0-72V
DC Current	5A	3A	1.5A
Power (max)	90W	108W	108W
Price	$199.00	$199.00	$199.00

Hantek 5000B Series Digital Storage Oscilloscopes

Introducing the Hantek 5000B Series Digital Storage Oscilloscopes. Available in 60MHz, 100MHz and 200MHz Bandwidths. Each one provides real-time sample rates up to 1GSa/s and equivalent sample rates up to 25GSa/s. In addition, they have a maximum 1M memory depth for better observation of waveform details. The 7 inch color TFT LCD Display with Windows-style interface and menus provide easy operation.

Abundant menu information and easy-to-use buttons give you plenty of measurement information:

The multifunctional knobs and the powerful shortcut keys help save time during operation.

The Autoset function lets you detect sine and square waves automatically.

The Probe Check Wizard guides you to adjust the probecompensation and set the Probe option attenuation factor.

Three help methods (context-sensitive, hyperlinks, and an index).

You can quickly master all functions to greatly improve your efficiency in production and development.

New Lower Introductory Prices!

Features:

60, 100 or 200 MHz bandwidth
1GSa/s Real Time sample rate
25GSa/s Equivalent sample rate
Large (7.0-inch) color display,WVGA(800x480)
Record length **1M**
Trigger modes: edge/pulse width/line selectable video/slop/overtime etc.
USB host and device connectivity, standard
Multiple automatic measurements
Four math functions, including FFTs standard
Provides software for PC real-time analysis

3 Models to choose from

DSO5062B
60MHz Digital Storage Oscilloscope

~~$385.00~~ $369.00*

www.circuitspecialists.com/dso5062b.html

DSO5102B
100MHz Digital Storage Oscilloscope

~~$499.00~~ $399.00*

www.circuitspecialists.com/dso5102b.html

DSO5202B
200MHz Digital Storage Oscilloscope

~~$599.00~~ $499.00*

www.circuitspecialists.com/dso5202b.html

*Discount does not apply to prior sales.

Circuit Specialists, Inc. 220 S. Country Club Dr., Mesa, AZ 85210
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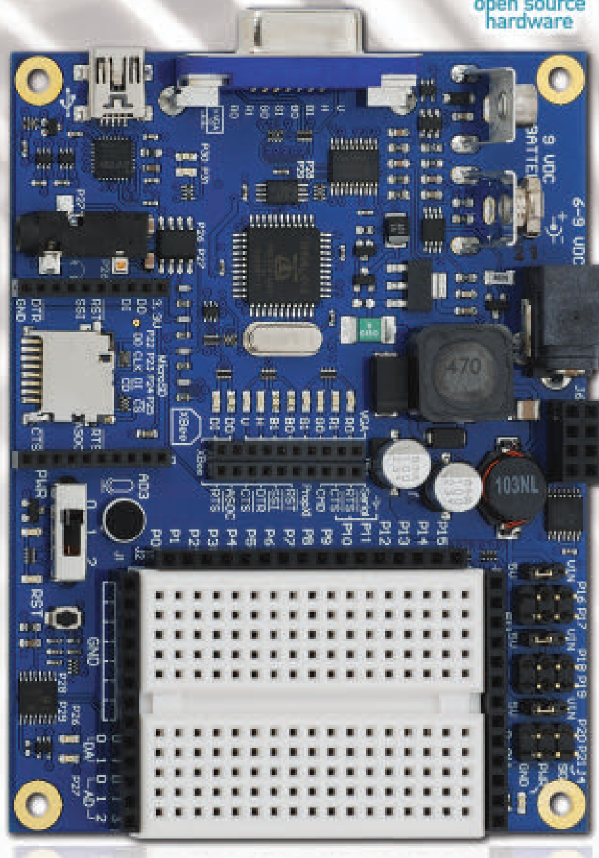
Eight processors
Eight benefits!

$129.00

open source hardware



Propeller Board Of Education

For more information: ***www.parallax.com/PropBOE***

Order **Propeller BOE (#32900)** at www.parallax.com or call our Sales Department toll-free 888-512-1024 (Monday - Friday, 8 AM - 5 PM, PDT)

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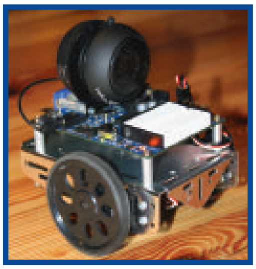
#1 Invest in yourself! — Develop products, program robots, or simply experiment.

#2 Complete Multicore Setup — The Propeller Board Of Education includes a full set of peripherals support an amazing array of projects:

- P8X32A microcontroller, 32 KB EEPROM, 5 MHz crystal
- XBee wireless transceiver socket
- SD Card socket for sensor data, large programs, etc.
- Microphone audio input and amplifier output
- VGA port for visual feedback
- (6) 3-pin servo/sensor ports
- 10-bit A/D and D/A
- Nearly 20 SMT LEDs for visual feedback
- Voltage regulators provide up to 3 A @ 5 V, 360 mA @ 3.3 V
- Power this board from USB, battery or wall supply

#3 Learn.parallax.com — Easy-to-follow web tutorials with beginner-friendly objects simplify Propeller programming for students and teachers who are new to the multicore environment. Just download the code and go! Example projects demonstrate the Propeller BOE's features, and provide inspiration for your own inventions.

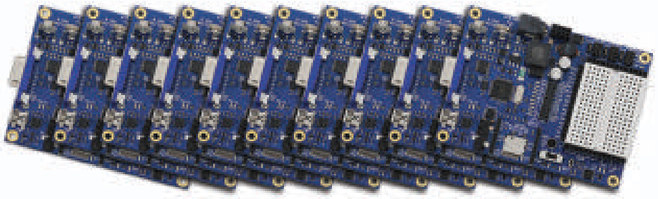
#4 Familiar Board Of Education Design — The Propeller BOE is based on the familiar, trusted design of the original BASIC Stamp Board Of Education used for learning microcontroller programming worldwide.



#5 Boe-Bot Compatible Mount the Propeller Board Of Education and a veho360 speaker on a Boe-Bot robot chassis. Assembly instructions, speech synthesis and navigation code are available on learn.parallax.com.

#6 Spin now, and C is on the way — Program in the Propeller microcontroller's native Spin language or, if you wish to program in C, follow the progress of the PropellerGCC project and download the Alpha code.

#7 Volume Discounts — A great value for educational customers, see the product page on www.parallax.com for quantity price breaks. Propeller Board Of Education 10-pack; #32901.



#8 Lifetime Warranty — Made in the USA. Parallax provides a limited Lifetime Warranty on craftsmanship.